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Modeling and Analysis of Semi-automated Fusion in the Intelligence Process

by Kristin M. Schweitzer

ARL-TR-5969 **March 2012**

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14. ABSTRACT
Technology today provides more data than humans can possibly analyze manually. Semi-automation fusion (SAF), where a system filters and fuses information in preparation for human analysis, is one way to process and organize vast amounts of data for more efficient human handling. The question that arises is how SAF will affect the human's workload. This analysis quantified the impact that SAF might have on mission times and the cognitive workload for four Infantry Battalion S2-level intelligence analysts. The objectives were to determine and compare workloads for the analysts when using a manual information analysis process and when using a SAF-assisted process. Of particular interest was the analysis time to discovery time ratio. For this model, the ratio was higher with the SAF process, indicating that analysts were able to better employ their time and skills on analysis rather than information gathering. However, improvement is still needed in order for the analysts to fully exploit the available information while maintaining a reasonable cognitive workload level.

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Intelligence, semi-automated, fusion, cognitive workload, IMPRINT modeling

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Contents

List of Figures

List of Tables

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1. Introduction

Over the past five years, requirements to anticipate political, military, economic, security, informational, and intelligence-based effects and explain local cultural dynamics relative to larger insurgent grievances have been added to the traditional intelligence support requirements. As a result, the demands on tactical Army intelligence analysts from commanders, staff officers, and collection planners have grown significantly in volume and complexity (Sensenig, 2009). To complicate matters, advancements in technology and capabilities have resulted in the continual production of a vast amount of information that must be filtered and analyzed before analysts can report their findings to their customers. Such information may be recorded in a wide range of formats and might contain data such as imagery, human reports, sensor data, or communications information.

For normal military operations, the bulk of an analyst's work typically involves the unit commander's priority intelligence requirement (PIR). Doctrinally, a PIR should be of short duration and answerable, and then updated in accordance with the continuing scheme of maneuver. It should also support a decision point, i.e., a time and place at which a commander decides on a friendly course of action to disrupt, delay, or destroy the enemy. However, with the increasing amounts of information flowing into databases and a steady number of analysts receiving an increasing number of requests for intelligence, much of the information is never even analyzed (Mathews, 2009).

One way to address the growing gap between how much information is available and how much is eventually refined into intelligence is to introduce semi-automated fusion (SAF) to the intelligence process. Fusion is the processes, technologies, and techniques used to transform data from multiple sensors into timely, accurate, and relevant information in order to support the commander's decision making. These processes, by their very nature involve both human reasoning and computer processing (Sensenig et al., 2010). Currently, humans perform most fusion tasks, but in the future, fusion software and technology are expected to refine raw data and present the relevant parts to the analyst, freeing the analyst from mundane collection and refinement tasks and enabling him to spend more time on higher level analysis. SAF is fusion with a human in the loop, monitoring the correlations made by fusion software and deciding whether the correlations are appropriate. The purpose of this analysis was to quantify the impact that SAF might have on mission times and intelligence analysts' cognitive workloads.

2. Methodology and Procedure

In order to quantify workloads and times, a task flow model for the intelligence process was created using the U.S. Army Research Laboratory's Improved Performance Research Integration Tool (IMPRINT). IMPRINT is a dynamic, stochastic, discrete event network modeling tool that can be used to help set realistic system requirements, identify Soldier-driven constraints on system design, and evaluate the capability of available manpower and personnel to effectively operate and maintain a system (U.S. Army Research Laboratory, 2009). It is also one of the few tools available that can model highly cognitive workload functions of a theoretical or early developmental stage system in an objective manner.

The information analysis process (i.e., the intelligence process) currently in use by the U.S. Army was compared to one possible near-term SAF-assisted solution. The hypothesis was that (1) analysts' cognitive workload would decrease with the assistance of SAF, (2) SAF would reduce the amount of time an analyst must spend on information gathering and refinement, and (3) SAF would increase the amount of time an analyst could spend on analysis.

The specific objectives of the analysis were (1) to determine the cognitive workload for individuals using a manual (i.e., unassisted) information analysis process and identify which tasks induced overload, if any; (2) to compare those results with the cognitive workload and any overload-inducing tasks for individuals using a SAF-assisted process; and (3) to compare the analysis time to information gathering (i.e., discovery) time ratio for the manual and SAF-assisted processes.

2.1 Information Analysis Process Model Overview

Both the baseline model of the information analysis process (completed without any automation) and the SAF-assisted model outline an Infantry Battalion S2 level intelligence team of four intelligence analysts (military occupational specialty [MOS] 35F) tasked with supporting their Battalion commander's PIR for one 12-h shift. One analyst is ranked E6 (skill level 30), one is an E4 (skill level 20), and two are E3s (E3-1 and E3-2, skill level 10).

The models begin with a shift change brief on the outgoing intelligence team's progress in completing the commander's PIR. The incoming team decides what assets and information will be needed. The E4, E3-1, and E3-2 have initial duties for requesting assets and setting software alerts, but then devote their attention to incoming reports and occasional non-analysis tasks. E6 has light analysis duties such as addressing smaller reports and continually reviewing asset needs, but is also expected to float and fill in where needed. For example, when one of the analysts becomes overloaded, the program attempts to assign some of the tasks to another operator (including E6). Sometimes, all other operators are busy, in which case the program will note the overload point with no contingency operators.

In addition to receiving large and small reports throughout the shift, the analysts must perform research and checks, collaborate with others, build briefs, and perform non-analysis tasks. The non-analysis task itself is programmed to be generic, but may represent activities such as breaks, errands, visitor briefs, or facility chores—none of which contribute to the analysis process.

The analysts are also required to address a mission interrupt procedure. Like the non-analysis task, the mission interrupt is programmed to be generic, but represents critical diversions such as troops in contact, time-sensitive targeting, or an isolating event (lost personnel). All four analysts are fully engaged for a variable amount of time. Communication levels are up and cognitive demand is high.

Figure 1 (see also appendix A) is the overall IMPRINT task flow for the baseline model. The pink rectangles are individual tasks and the gray rectangles are functions that contain multiple tasks (which are not shown in the figure). The ivory rectangles contain comments that serve to describe the model.

The resulting workload values from the baseline model were used to identify areas where the task flow would benefit from automation. The SAF model was a modified form of the baseline model that incorporated tasks completed by a semi-automated system. While the four analysts were relieved of some tasks due to SAF, they also had to perform additional tasks since they act as oversight on the SAF system.

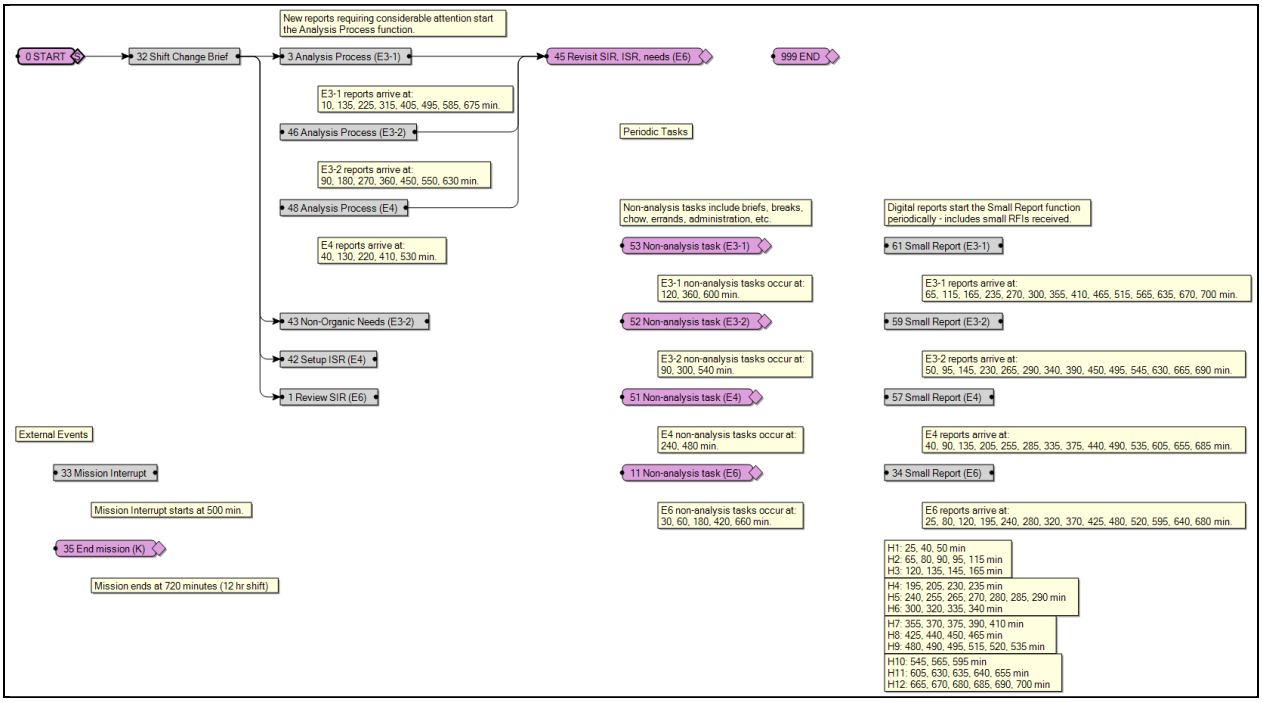

Figure 1. Information analysis network.

2.1.1 Assumptions and Caveats

The model looks at a "typical" 12-h shift for a Battalion-level intelligence team. One of the difficulties encountered with trying to model any intelligence task is the highly cognitive aspect of the job. Some pieces of information may take seconds to process while others may take hours to research. In a relaxed environment, analysts may take as much time as they need to be thorough. In a high intensity environment, analysts are pressed to research, analyze, and prepare intelligence as quickly as they are able, often resulting in a lower confidence level for the report. Given such variability, the model was designed with some task times that have large standard deviations.

A second issue that had to be addressed within the model is that people are often able to focus on only one or two tasks at a time, depending upon the mental resources needed (Wickens and Hollands, 2000). The model was intentionally designed to maintain all tasks as they were assigned, which caused a recurring overload situation for all of the operators. The purpose was to see just what is being asked of the human analyst. The result is a quantification of the hypothetical workload for a company level intelligence analyst and an identification of which tasks might best be automated.

2.1.2 Naming Convention

An IMPRINT model is composed of tasks and functions, connected in a chronological fashion to demonstrate the flow of activities for a particular assignment. A task is the basic building block for the model and represents a single duty such as reading a report. A function is a more complex activity such as analyzing a report that is built of multiple tasks. Throughout this report, specific function names are indicated by italics and title case capitalization. Specific task names are also indicated by italics, but use sentence case capitalization.

2.2 Baseline Model

The model begins with the E6 giving a *Shift Change Brief* to the E4, E3-1, and E3-2. The brief is 10 min long for everyone, with no variance, and no other tasks occur during the brief. Once the *Shift Change Brief* is finished the *Non-Organic Needs, Setup ISR* (Intelligence, Surveillance, Reconnaissance), and *Review SIR* (Specific Information Requirements) functions all begin concurrently. The first major report arrives, triggering the *Analysis Process* function, and then the other activities such as other major reports, small reports, and non-analysis tasks arrive with regularity as noted in figure 1. *Mission Interrupt* is called at 500 min to simulate a high-level tasking that requires all analysts' attention.

2.2.1 Review SIR

The E6 reviews the PIR and develops the SIR (*Review SIR*). It is his duty to ensure the team is working towards the same goal of answering the commander's PIR. He reads the PIR, considers the different aspects involved, and communicates with people to either clarify points or request

more specifics. He develops indicators, which are observable activities an enemy may take in order to conduct any particular course of action; he decides when and where a collection asset should be able to observe or detect an indicator; and he sets alarms that flag relevant information within the analysis software and alert him when the program finds it. The E6 also performs all subsequent reviews of the PIR (*Revisit SIR, ISR, needs*) throughout the mission.

Figure 2 (see also appendix A) is the IMPRINT task flow for *Review SIR*. The diamond-shaped nodes contain a letter that designates the type of path connecting one task or function to another. "S" indicates a singular path, "M" indicates multiple and concurrent paths, and "P" indicates a probabilistic path. Task 1_17 *Review SIR (listen)* has two paths leading from it. The top path will be taken 70% of the time and leads back to Task 1_10 *Review SIR (talk)* and the bottom path will be taken 30% of the time and leads forward to Task 1_18 *Review SIR Done (K)*. The same process is used for Task 1_5 *Set alarms (E6)*. The top path to Task 1_21 *Develop indicators (E6 decide)* will be taken 50% of the time and the *Review SIR* function will *End* 50% of the time.

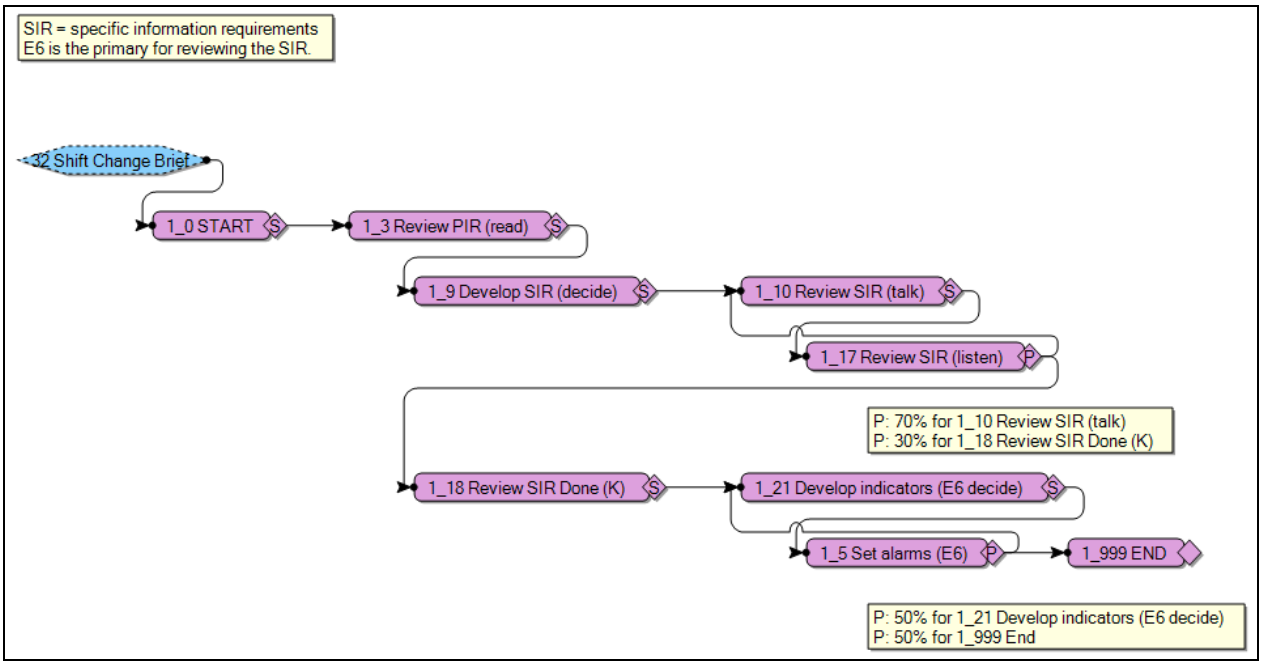

Figure 2. Baseline function *Review SIR*—develop specific information requirements.

2.2.2 Setup ISR

The E4 sets up the ISR requests (*Setup ISR*). The function requires a review of what ISR assets are needed in order to acquire the appropriate information to satisfy the SIR, what assets are available at the Battalion level, and what assets must be requested from other units. The E4 reviews the PIR and SIR, prioritizes the tasks for each ISR asset and resource, communicates with people, and then adds the reporting criteria indicators to the alarms within the analysis software. The E6 performs any subsequent reviews of the ISR asset status (*Revisit SIR, ISR, needs*) throughout the mission.

Figure 3 (see also appendix A) is the IMPRINT task flow for the *Setup ISR* function. The E4 always begins by reading the PIR and SIR (*Review SIR (read)*), but the following task varies. Sixty percent of the time the E4 will decide what ISR tasks are needed and how they might be accomplished; 25% of the time he will communicate with someone, whether it is to verify information, request assets, etc.; and 15% of the time the ISR task will not require additional work and will proceed directly to indicator development. ISR task development and communication are iterative processes, as are indicator development and alarms.

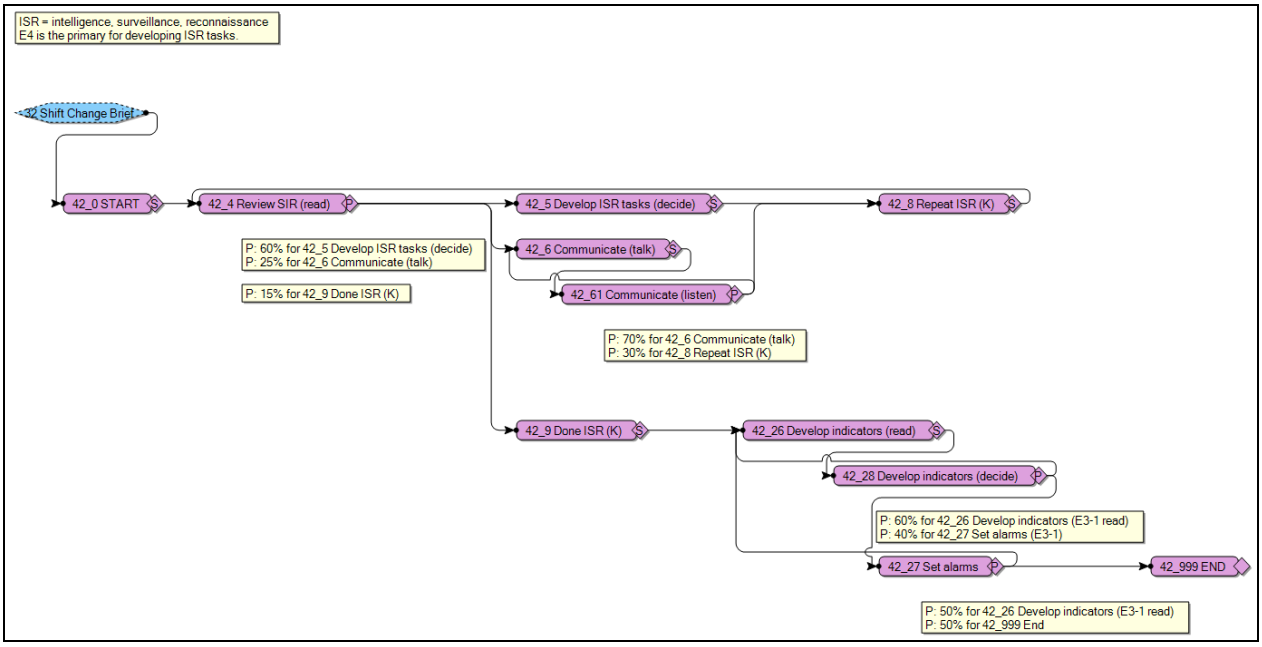

Figure 3. Baseline function *Setup ISR*—develop intelligence, surveillance, and reconnaissance tasks and requirements.

2.2.3 Non-organic Needs

The E3-2 identifies *Non-Organic Needs*. Non-organic needs are any requirements the Battalion has for information that cannot be obtained within the Battalion, including ISR assets that must be requested. The E3-2 reviews the PIR and SIR, identifies resource requirements and which ones must come from outside the Battalion (non-organic), communicates with people, and then adds the reporting criteria indicators to the alarms within the analysis software. He works closely with the E4 who is handling the ISR asset requirements within the Battalion. Just as with the ISR review, the E6 performs any subsequent reviews of the non-organic needs status (*Revisit SIR, ISR, needs*) throughout the mission.

Figure 4 (see also appendix A) is the IMPRINT task flow for identifying non-organic needs. It is identical to the *Setup ISR* function except that the focus is on non-organic assets rather than ISR assets, though the two may, at times, overlap.

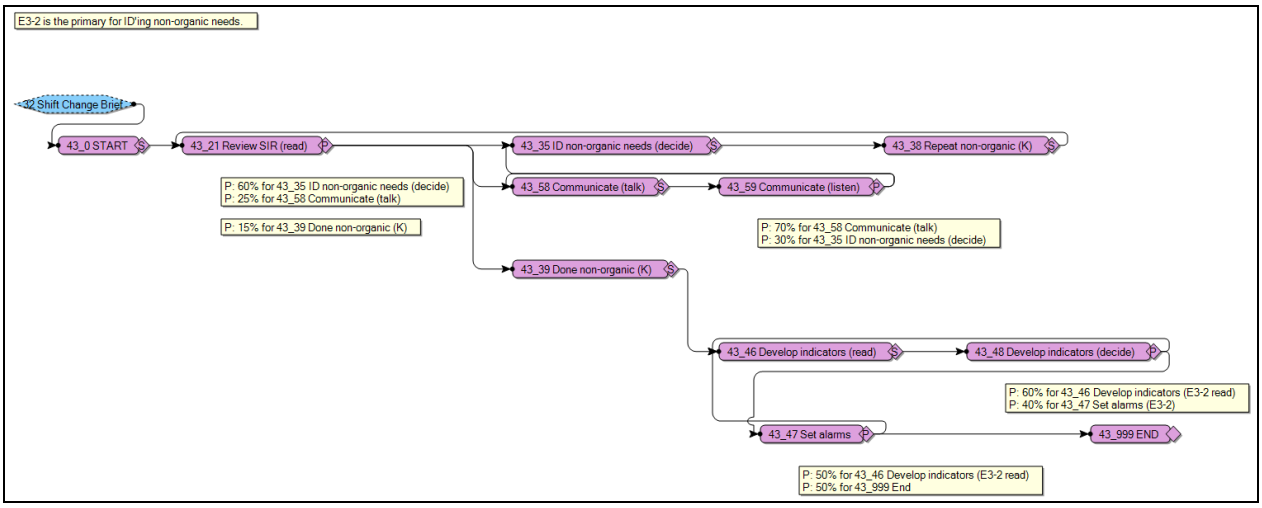

Figure 4. Baseline function *Non-Organic Needs*—develop non-organic asset and information requirements.

2.2.4 Mission Interrupt

The *Mission Interrupt* function requires the attention of all four analysts at the 500-min mark. It contains generic tasks meant to simulate urgent, high priority intelligence demands such as time-sensitive targeting, troops in contact, or an isolating event. As programmed, the *Mission Interrupt* tasks are in addition to the analysts' regular duties, not replacements for the regular duties. See figure 5 and/or appendix A.

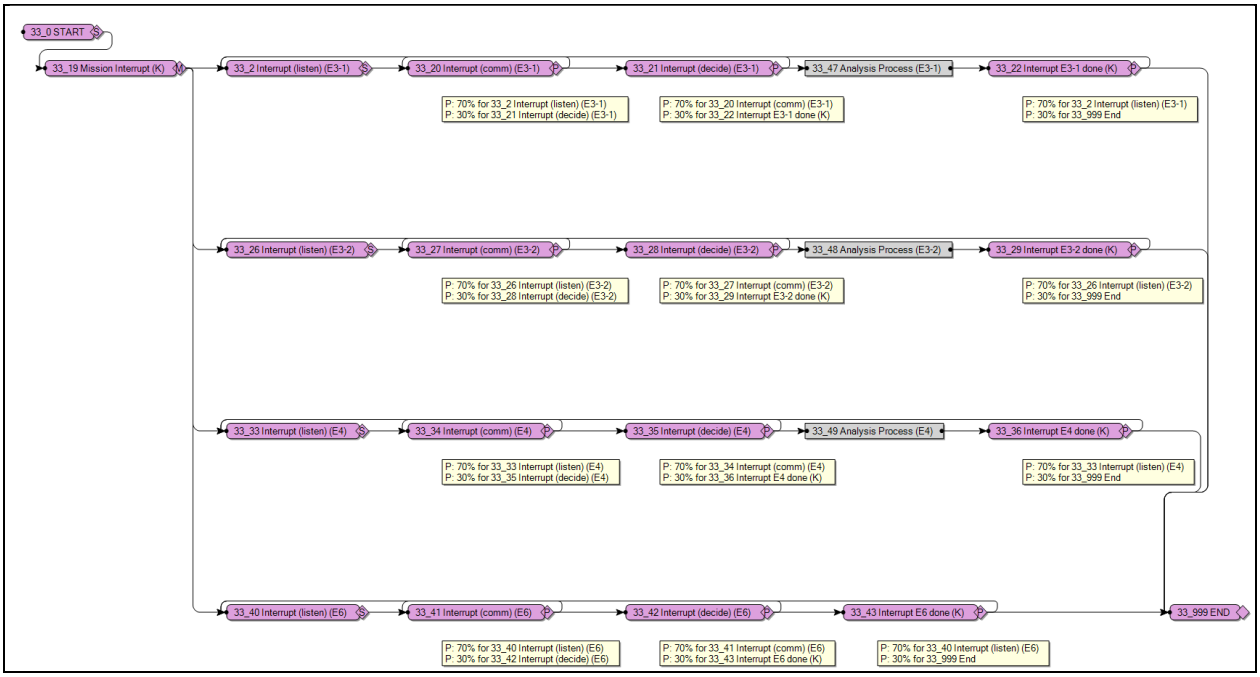

Figure 5. Baseline function *Mission Interrupt*—urgent, high priority intelligence support.

2.2.5 Periodic Activities

Two functions and one task are called repeatedly throughout the mission. The *Analysis Process* function represents an incoming report that requires significant attention and time. The *Small Reports* function represents incoming reports that still require significant attention, but require much less time than the larger reports in *Analysis Process*. Short *Non-analysis tasks* such as breaks, errands, or briefs are required of all four analysts occasionally throughout the shift. The comment boxes in figure 1 note the times that each activity is called.

2.2.6 Analysis Process

E3-1 begins research and analysis on the first large report that arrives, but the E3-2 and E4 also attend to the larger reports as they arrive. *Analysis Process* is called eight times for the E3-1, seven times for the E3-2, and five times for the E4. The model does not assign any of the larger reports directly to the E6, but he is used as a contingency operator for *Analysis Process* if all other analysts are overloaded. At the end of each *Analysis Process*, regardless of which analyst completed the analysis, the E6 reviews the PIR, SIR, ISR, and non-organic needs (*Revisit SIR, ISR, needs*) and updates them if needed.

Figure 6 (see also appendix A) is the Analysis Process task flow. The *Analysis Process* was intentionally programmed to vary widely in order to account for the extreme variance in task complexity that an analyst will encounter. The first step in the full *Analysis Process* is that a report arrives in either a *Verbal format* such as a phone call or face-to-face meeting or a *Written format* such as a digital report. Reports are in the *Verbal format* 70% of the time and require communication to clarify some points and writing for note-taking. Reports arrive in *Written format* 30% of the time and only need to be opened and read.

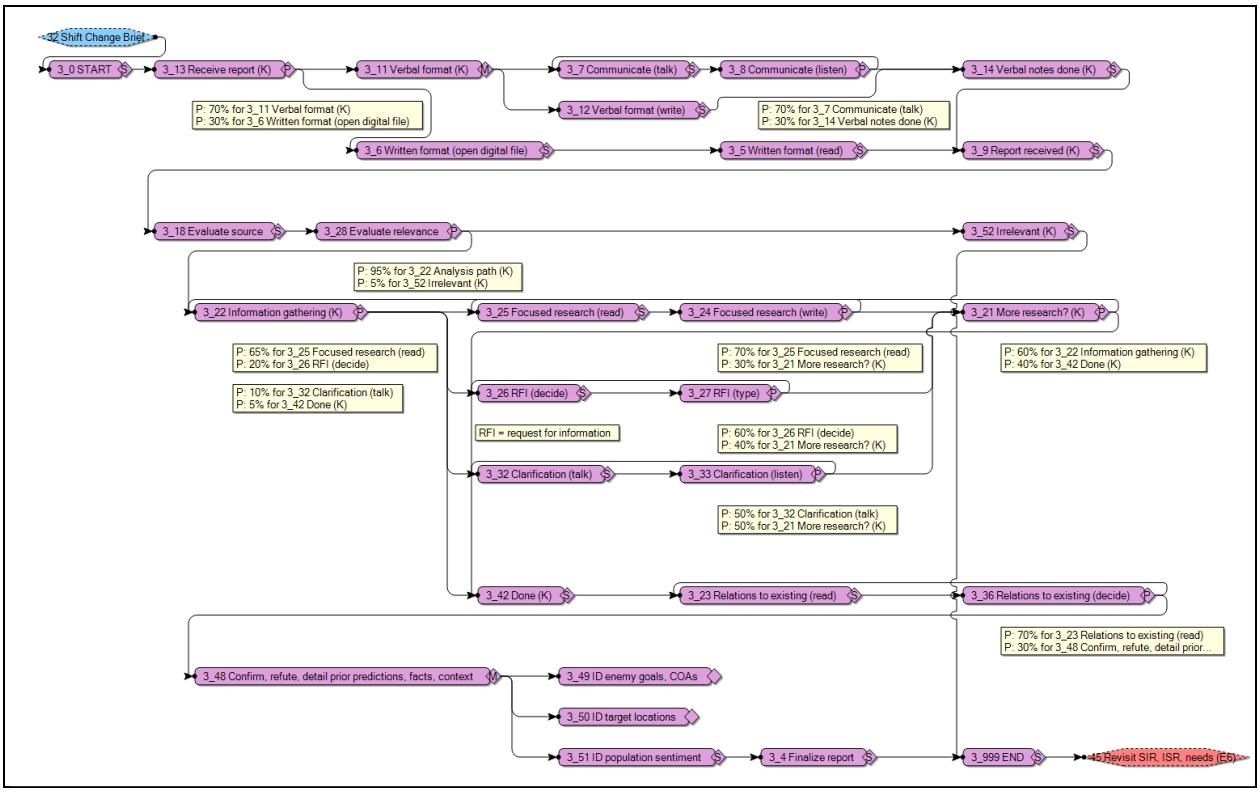

Figure 6. Baseline function *Analysis Process*—receive, research, and analyze a major report.

The second step is to *Evaluate the source* and *Evaluate the relevance*. If the report is irrelevant (which is 5% of the time), the *Analysis Process* ends. If the report is relevant (which is 95% of the time), the *Analysis Process* continues.

Information gathering and refinement begins in the third step with Task 3_22 *Information gathering (K)*. The probabilistic path proceeds to either *Focused research*, *RFI* (request for information), *Clarification*, or *Done*. For the first three tasks—*Focused research*, *RFI*, and *Clarification*—the whole process will repeat itself (back to *Information gathering (K)*) 60% of the time and will be *Done* 40% of the time. For the refinement part of the process that follows information gathering, the operator looks for *Relations to existing* reports and information and places the new report into context with prevalent conditions and circumstances.

In the fourth and final major step, the actual analysis is performed. The analyst must *Confirm, refute, detail prior predictions, facts, context*. Once that task is complete, the analyst concurrently tries to identify enemy goals and potential courses of action, identify any target locations, and identify the local population's sentiment regarding allied forces. Once all three tasks are complete the analyst finalizes the report and then the *Analysis Process* function ends.

2.2.7 Small Report

Small Reports come in continuously throughout the mission, and while they require minimal analysis and time, they still must be addressed. All four analysts receive 14 *Small Reports* each during the shift. The operator first opens and reads the report, takes notes, does some quick research, and then either validates the report (*Confirm, refute, detail*) or *Collaborates* with others. See figure 7 and/or appendix A.

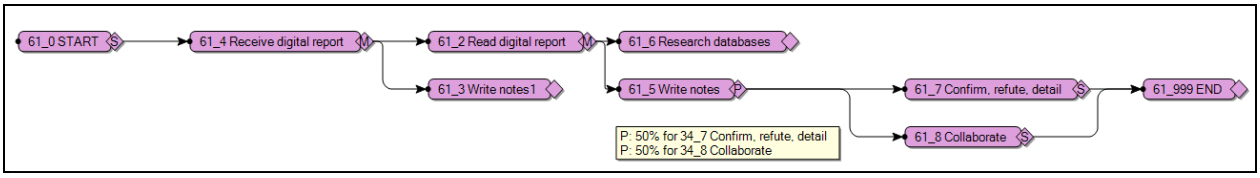

Figure 7. Baseline function *Small Report*—receive, research, and analyze a minor report.

2.2.8 Non-analysis Task

Short *Non-analysis tasks* such as breaks, errands, or briefs are called throughout the shift. The E3-1 and E3-2 are each assigned three non-analysis tasks, the E4 is assigned two, and the E6 is assigned five.

2.3 SAF Model

Fusion transforms data from multiple sensors into information a commander can use to form and support decisions. For this model, the fusion process is semi-automated, meaning that a computer performs the basic fusion functions and a human must verify and analyze the prepared information.

2.3.1 Changes from the Baseline Model

The SAF model is identical to the Baseline model for the Shift Change Brief, Non-Organic Needs, Setup ISR, and Review SIR functions. Revisit SIR, ISR, needs (E6) and Non-analysis tasks are also unchanged.

The *Analysis Process* function in the main network as well as the one nested within the *Mission Interrupt* function was modified for the SAF model. The *Evaluate source* and *Evaluate relevance* tasks were eliminated, along with the option of an *Irrelevant (K)* report. The other modifications were changes in the probabilities for certain paths (table 1). The changes were based upon the concept that the SAF would reduce the iterations that require human input, thus reducing analyst workload. The modified *Analysis Process* task flow used in the SAF model is in figure 8 (see also appendix A).

For the *Small Report* function the *Research databases* and the second occurrence of *Write notes* tasks were both eliminated. A task to *Check pedigree* was added to the SAF version. See figure 9 and/or appendix A.

Table 1. Changes in path probabilities for the *Analysis Process* function.

	Baseline (%)	**SAF (%)**
Information Gathering (K)		
Focused research (read)	65	20
RFI (decide)	20	10
Clarification (talk)	10	10
Done (K)	50	60
Focused Research (write)		
Focused research (read)	70	30
More research? (K)	30	70
RFI (type)		
RFI (decide)	60	30
More research? (K)	40	70
More Research? (K)		
Information gathering (K)	60	30
Done (K)	40	70
Relations to Existing (decide)		
Relations to existing (read)	70	30
Confirm, refute, detail prior…	30	70

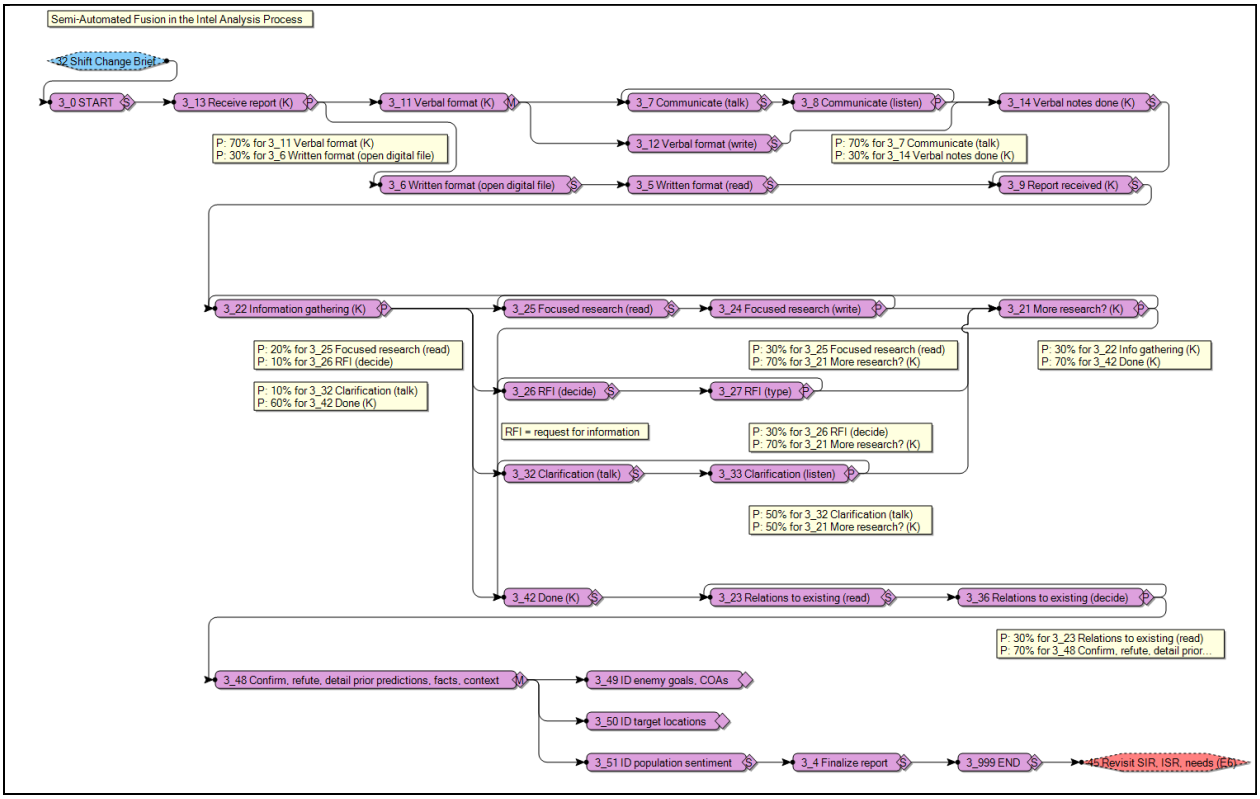

Figure 8. SAF function *Analysis Process*—receive, research, and analyze a major report.

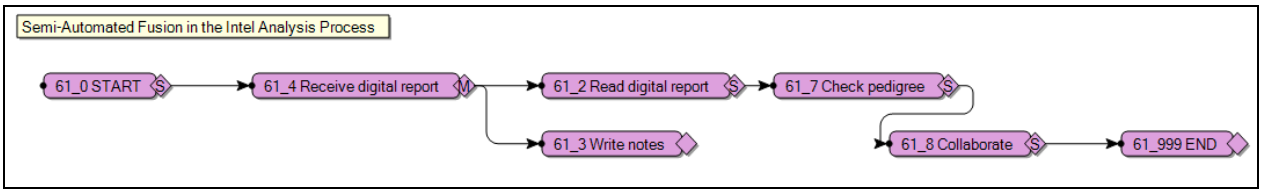

Figure 9. SAF function *Small Report*—receive, research, and analyze a minor report.

As stated earlier, the *Analysis Process* function that is nested within *Mission Interrupt* was modified in the same way the main model's function was. The other changes for *Mission Interrupt* are summarized in table 2. Again, the changes were made with the assumption that the SAF would reduce the frequency of human input and the analyst's workload. The modified *Mission Interrupt* task flow used in the SAF model is in figure 10 (see also appendix A).

Table 2. Changes in path probabilities for the *Mission Interrupt* function.

	Baseline (%)	**SAF (%)**
Interrupt E3-1 done (K)		
Interrupt (listen) (E3-1)	70	60
END	30	40
Interrupt E2-1 done (K)		
Interrupt (listen) (E3-2)	70	60
END	30	40
Interrupt E4 done (K)		
Interrupt (listen) (E4)	70	60
END	30	40
Interrupt (decide) (E3-1)		
Interrupt (comm) (E3-1)	70	30
Analysis Process (E3-1)	30	70
Interrupt (decide) (E3-2)		
Interrupt (comm) (E3-2)	70	30
Analysis Process (E3-2)	30	70
Interrupt (decide) (E4)		
Interrupt (comm) (E4)	70	30
Analysis Process (E4)	30	70

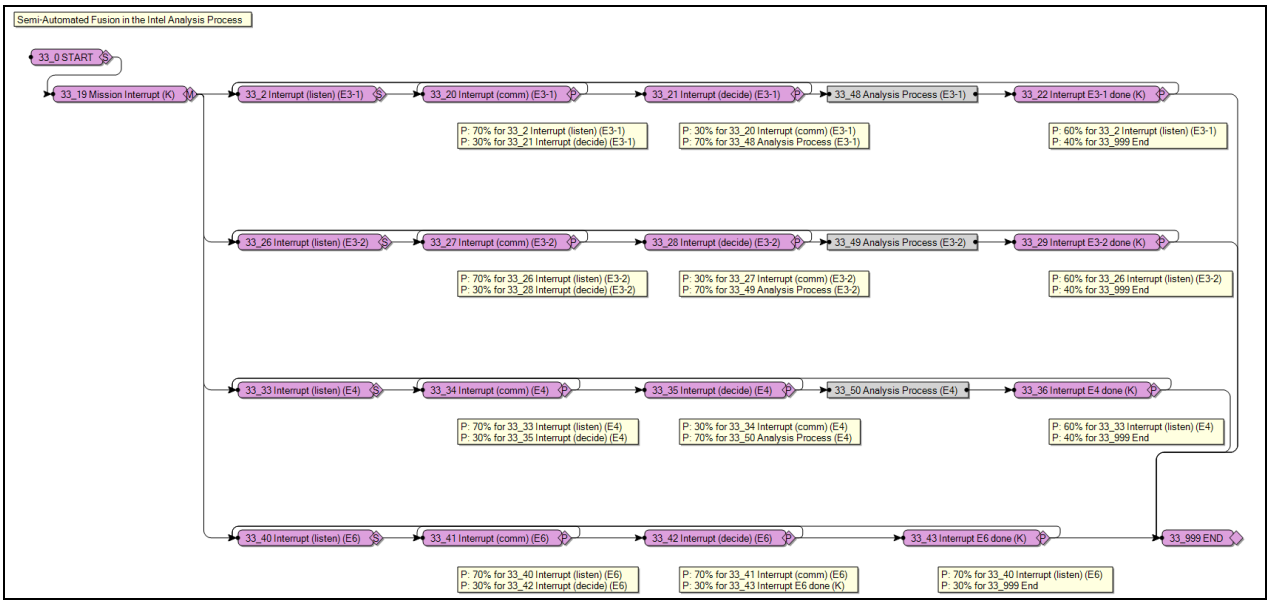

Figure 10. SAF function *Mission Interrupt*—urgent, high priority intelligence support.

3. Results

3.1 Overall Mission

Both models were allowed to run until completion 100× even though the time of interest is a 12-h shift. This enabled IMPRINT to calculate averages and frequencies using all the tasks and functions, rather than only the ones that were complete by the end of the shift (720 min).

As a result, the Baseline model ran anywhere from 380 to 10,601 min (almost 170 h, or just over 7 days), with an average mission time of 2268 min (about 38 h). In comparison, the SAF model ranged from 630–6,109 min with an average of 1770 min (about 29.5 h). The variability in mission durations is charted in figure 11. The Baseline model produced a non-parametric distribution due in a large part to the probabilistic nature of many of the functions and the high level of variance programmed for each task. Several of the tasks with a high standard deviation for time were eliminated for the SAF model because the tasks were performed by the semi-automated system. As expected, the SAF-assisted analysis produced a more normal distribution of mission times.

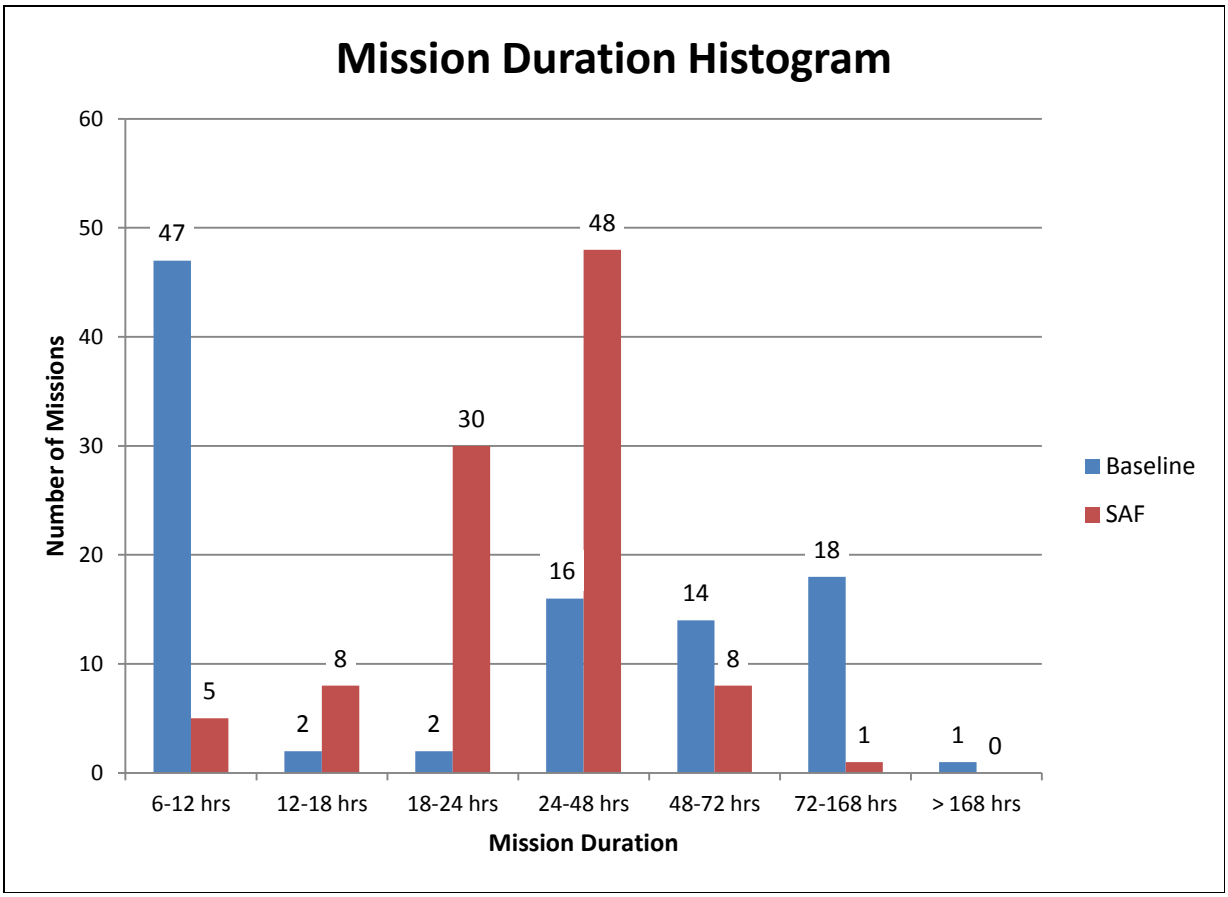

Figure 11. Histogram for mission duration—100 runs each for the baseline model and the SAF model.

Workload for the 12-h shift was averaged from 30 runs. IMPRINT calculates workload by summing the values (1–7) for each resource channel—auditory, cognitive, fine motor, speech, and visual—of all concurrent tasks. For example, if a single task has maximum values for each resource channel the overall workload would be 31. The description for maximum workload in the auditory channel it is to interpret sound patterns ($workload_{max}$ = 7); in the cognitive channel, it is estimation, calculation, or conversion ($workload_{max}$ = 7); in the fine motor channel, it is serial discrete manipulation such as typing ($workload_{max}$ = 7); in the speech channel, it is complex sentences ($workload_{max}$ = 4); and in the visual channel, it is to visually scan/search monitor such as a continuous/serial inspection ($workload_{max}$ = 6). Given that humans can reasonably perform no more than two tasks at a time, the overload threshold was set by rounding the maximum possible workload for two concurrent tasks to 60.

Table 3 shows that for every operator the SAF process produced a lower relative workload demand than the human-only process. While the average workload values give the impression that workload was infrequently above the overload threshold of 60, figure 12 shows that the E3-1's workload was often much higher than 60, peaking at 109.2 at 645 min for that particular run.

Table 3. Workload demands for one 12-h shift, calculated from 30 runs.

	Relative Average Workload				Peak Workload		
Analyst	**Baseline**	**SAF**	**% Change**		**Baseline**	**SAF**	**% Change**
E3-1 (35F10)	64.0	56.5	–11.7%		122.3	110.5	–9.6%
E3-2 (35F10)	62.9	52.5	–16.5%		132.0	120.1	–9.0%
E4 (35F20)	59.8	49.0	–18.0%		140.6	112.2	–20.2%
E6 (35F30)	48.5	36.0	–25.8%		123.2	108.3	–12.1%

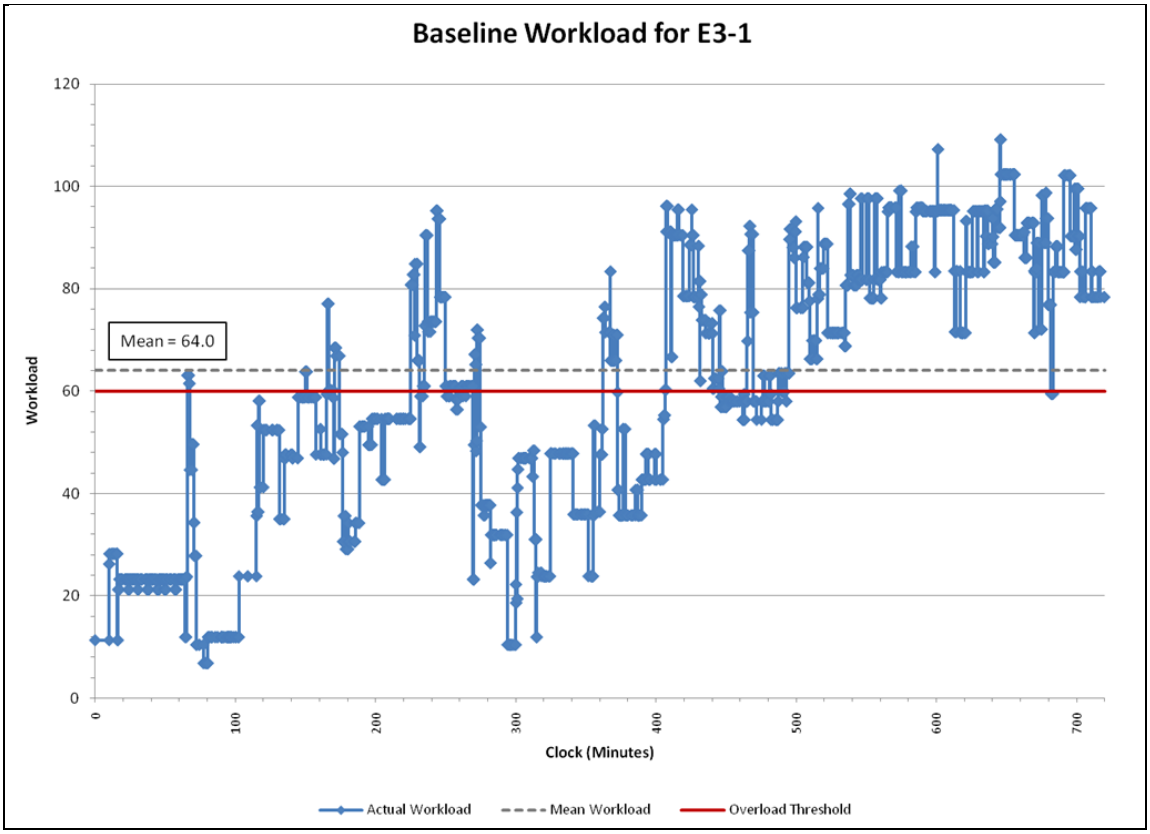

Figure 12. Actual, average, and overload workload demands for the E3-1 in the baseline model.

Appendix B contains graphs of the actual workload, the average workload, and the overload threshold for each analyst for the first 12 h of a single mission run.

3.2 Reports

For each mission in both the Baseline and SAF models, the team of analysts received 76 reports in the first 12 h. Fifty-six were smaller reports that required minimal time and attention, and 20 were more extensive reports that required substantial time and attention. Since the focus is on the 12-h shift, no reports were received after 12 h.

For the Baseline model *Small Report* averaged 11 min. Even though the *Research databases* task and the second occurrence of the *Write notes* task were both eliminated for the SAF model,

the *Check pedigree* task that was added pushed the *Small Report* average for the SAF model to 16 min. Times for the full reports averaged 116 min for the Baseline and 93 min for the SAF.

3.3 Analysis Versus Discovery Time

One of the objectives of analyzing the IMPRINT models was to determine whether SAF increased the amount of time analysts could spend on analysis or decreased the amount of time spent on discovery.

Discovery, or information gathering, consists of the following:

- Evaluate source,
- Evaluate relevance,
- Focused research (read),
- Focused research (write),
- RFI (decide),
- RFI (type),
- Clarification (talk),
- Clarification (listen),
- Relations to existing (read), and
- Relations to existing (decide).

The goal of SAF developers is to provide a program that will perform all of these tasks without operator input. The product would be data that is refined to the point where an analyst can begin directly with analysis and avoid further data preparation. For these models, analysis consists of the Confirm, refute, detail prior predictions, facts, context; ID enemy goals, course of actions (COAs); ID target locations; and ID population sentiment tasks.

For the Baseline model analysts averaged 116 min spent on actual analysis and 66 min on discovery—a ratio of 1.75. For the SAF model analysts averaged 112 min on analysis and 42 min on discovery for a ratio of 2.68.

3.4 Non-analysis Tasks

The team had 13 non-analysis related tasks to perform that averaged 15 min in both models.

3.5 Mission Interrupt

Mission Interrupt was programmed to take the analysts away from their normal tasks and focus them on a pressing, external tasking that requires high levels of attention. For these models, the interrupting tasks were in addition to the analysts' regular duties and included communications

and analysis. The average time spent on the Baseline *Mission Interrupt* was 2062 min, as compared to an average of 771 min spent on the SAF *Mission Interrupt*.

4. Discussion

4.1 Time

Considering the nature of intelligence tasks independent of personnel shifts, the times are realistic. A simple PIR may take very little time to answer, while an elaborate PIR involving multiple units and assets would take much longer to fully analyze and report. In a working intelligence unit, the next shift of analysts would pick up where the previous shift left, so the work never really stops.

The drastic variability apparent in the task and function times, especially with the Baseline model, are the product of intentionally large variances and highly probable repeating paths. Adjustments for the SAF model reduced the likelihood of repeating paths, but maintained the large variances. While the changes did not increase the amount of time spent on analysis, they did reduce the time spent on discovery, which is a goal of most streamlining processes for the intelligence process. The end result is that the analysis to discovery time ratio was higher for SAF-assisted analyses.

4.2 Workload

Workload demand frequently spiked or remained above the generally accepted overload threshold of 60 for both models. When workload is above 60, most individuals will drop tasks and make mistakes in an effort to keep up with the cognitive challenges. These models were intentionally programmed to maintain all tasks rather than to drop tasks when the workload became too high so that the extent of the overload conditions could be analyzed.

No single task consistently caused the overload. Typically, when the analyst was significantly overloaded, he was performing multiple inquiries or analyses at the same time. When the workload demand hovered in the 90s and above, the analyst was often working on up to seven separate tasks at the same time. Five to six concurrent tasks would often cause workloads between 60 and 80.

In reality, when a new report arrives, humans will normally either drop the current report to focus on the new one or ignore the new report and finish the old one. In the models, analysts were expected to keep up with the work as it arrived. The purpose in writing the models in this manner was to demonstrate what is expected of military analysts. If they perform the tasks sequentially, which would allow thorough attention to each report, the process will take too long. If they perform the tasks in parallel, as they do in the models, the analysts may not be able to focus properly on the many tasks at hand.

5. Conclusions

The objectives of this analysis were to determine and compare the cognitive workloads for analysts using a manual information analysis process and those using a SAF-assisted process; identify which tasks induced overload, if any; and compare the analysis time to discovery time ratio for the manual and SAF-assisted processes.

The relative average and peak workload demands were lower for all four analysts with the inclusion of SAF. Combined with the fact that workloads still exceed acceptable levels for accurate and efficient performance at many points, results generated by the models indicate that SAF positively contributes to the information analysis process, but more improvement is still needed in order to enable analysts to fully exploit the available information.

Overload was not consistently initiated by any single task, but was a result of parallel tasks. This implies the need for procedural improvements rather than task-specific assistance in the intelligence process.

The analysis time to discovery time ratio was increased with SAF, indicating that analysts were able to better employ their time and skills on analysis rather than information gathering.

Overall, SAF as modeled here positively influenced the intelligence process, but not in a drastic manner. Review of the workload details indicates that analysts are expected to perform several concurrent, highly cognitive tasks without dropping any of them. In order to reduce the frequency or even occurrence of overload, SAF would need to expand to include more tasks such as additional correlation capabilities.

6. References

Mathews, W. Managing the Data Tsunami. Retrieved 30 March 2010 From Defense News. http://www.defensenews.com/story.php?i=4149911 (accessed 22 June 2009).

Sensenig, R. All Source Intelligence Analyst, Retired, (K. Schweitzer, Interviewer), July 2009.

TC 2-33.4. *Intelligence Analysis*; U.S. Army Intelligence Center, U.S. Department of the Army, Fort Huachuca, AZ, July 2009.

U.S. Army Research Laboratory. Improved Performance Research Integration Tool, Retrieved 3 March 2010, U.S. Army Research Laboratory. http://www.arl.army.mil/www/default.cfm?Action=445&Page=445 (accessed 6 March 2009).

Wickens, C. D.; Hollands, J. G. *Engineering Psychology and Human Performance*; Prentice Hall: Upper Saddle River, NJ, 2000.

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Appendix A. Network Figures (Enlarged)

Figures A-1 through A-10 show enlarged version of the network figures shown in the main report.

This appendix is in its original form without editorial change.

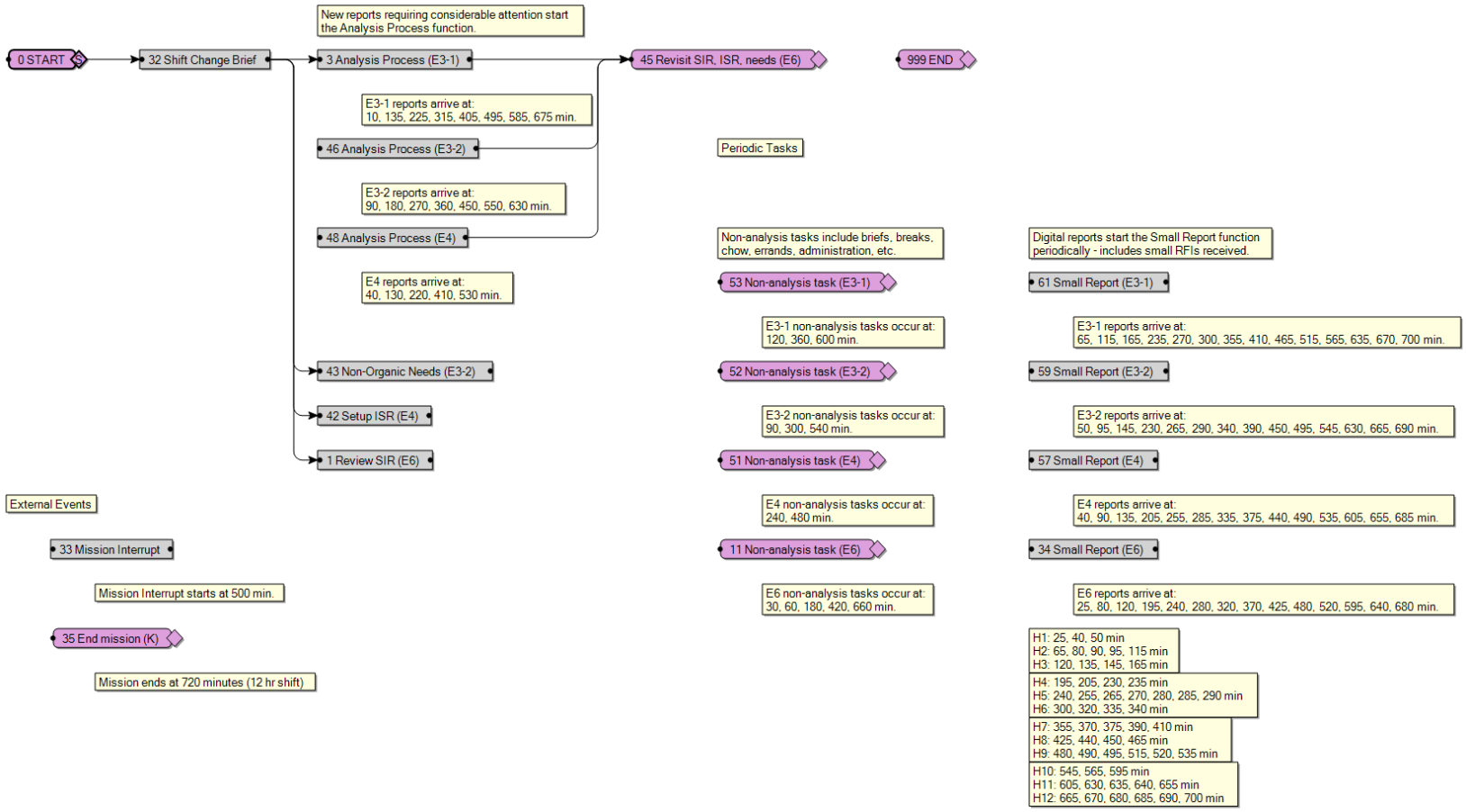

Figure A-1. Information Analysis Network (from page 3).

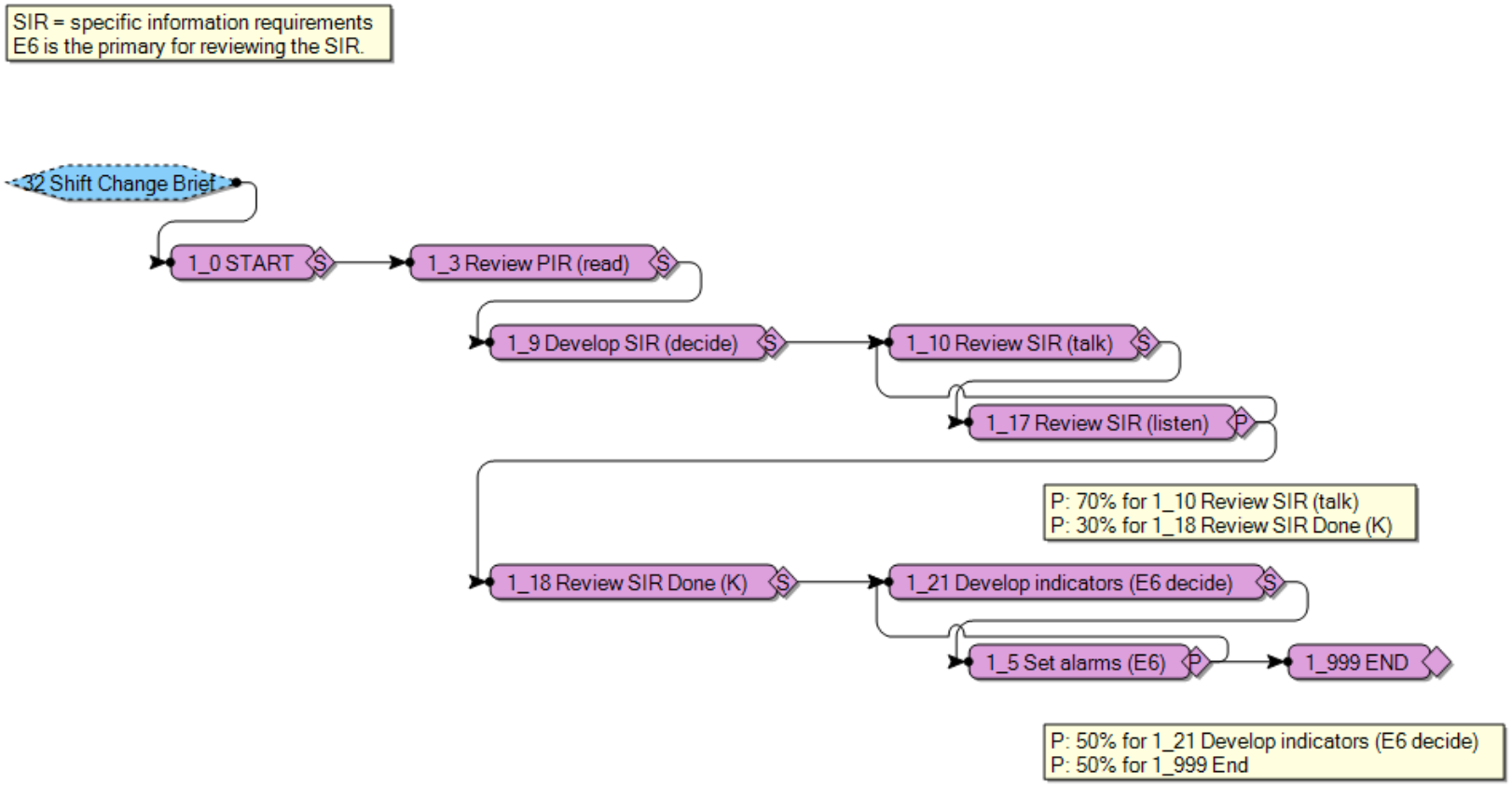

Figure A-2. Baseline Function *Review SIR* (from page 5).

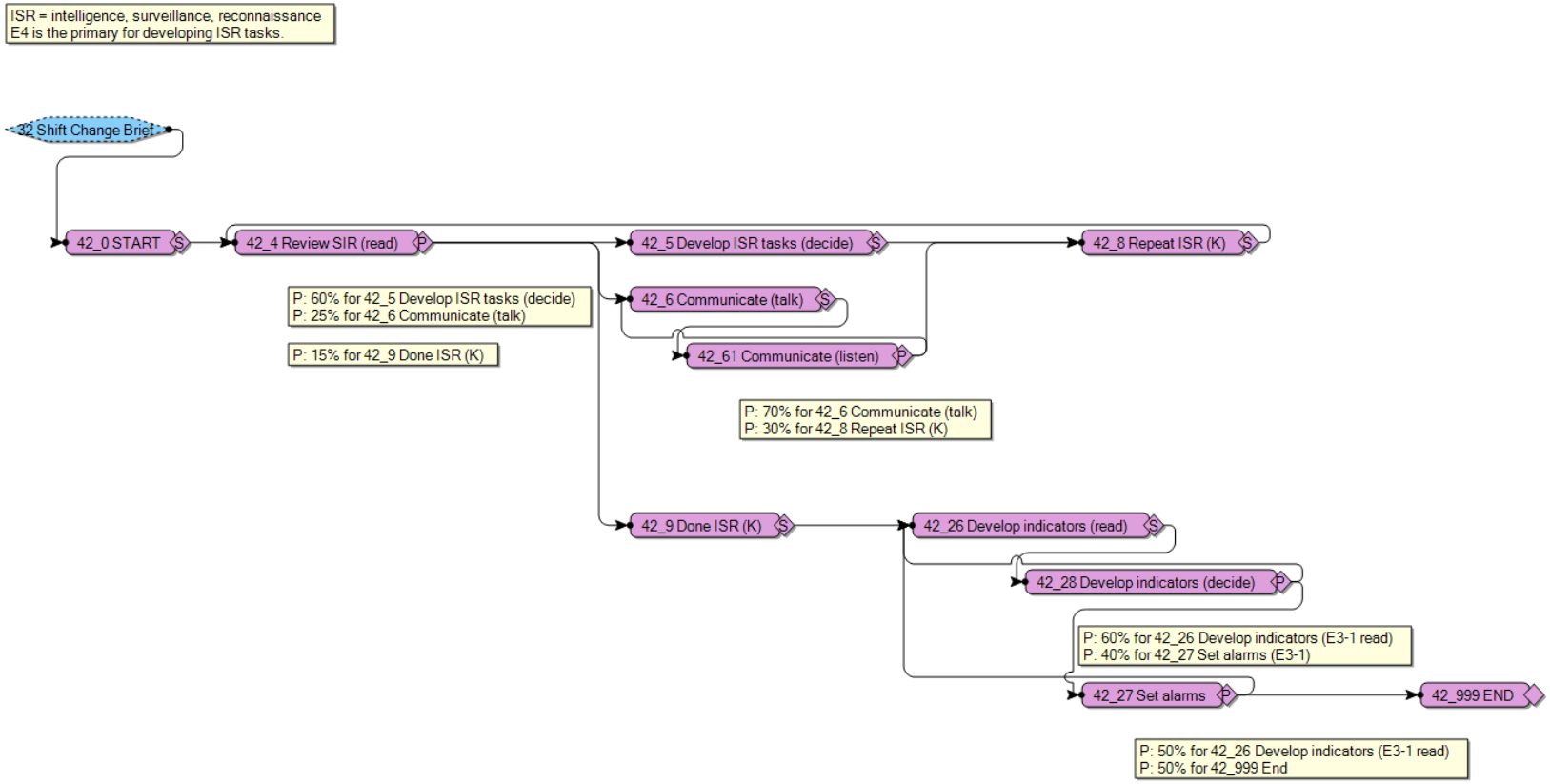

Figure A-3. Baseline Function *Setup ISR* (from page 6).

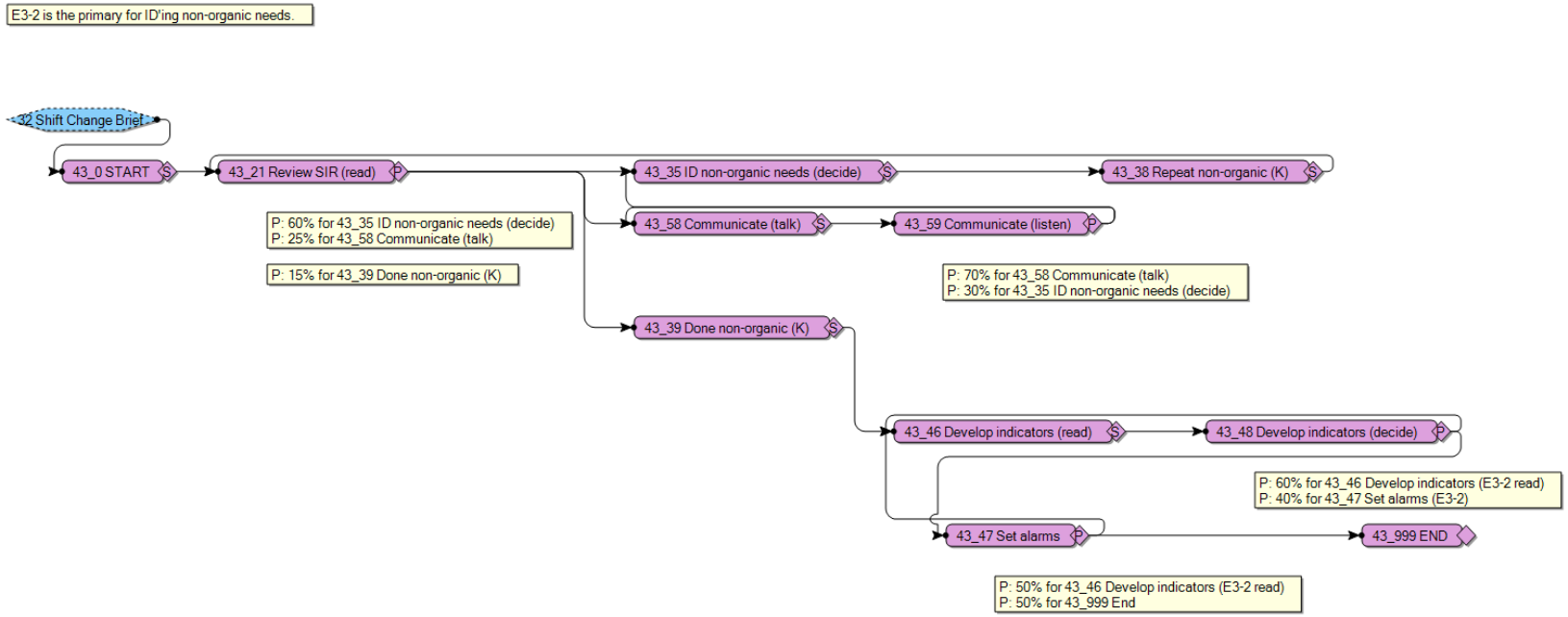

Figure A-4. Baseline Function *Non-Organic Needs* (from page 7).

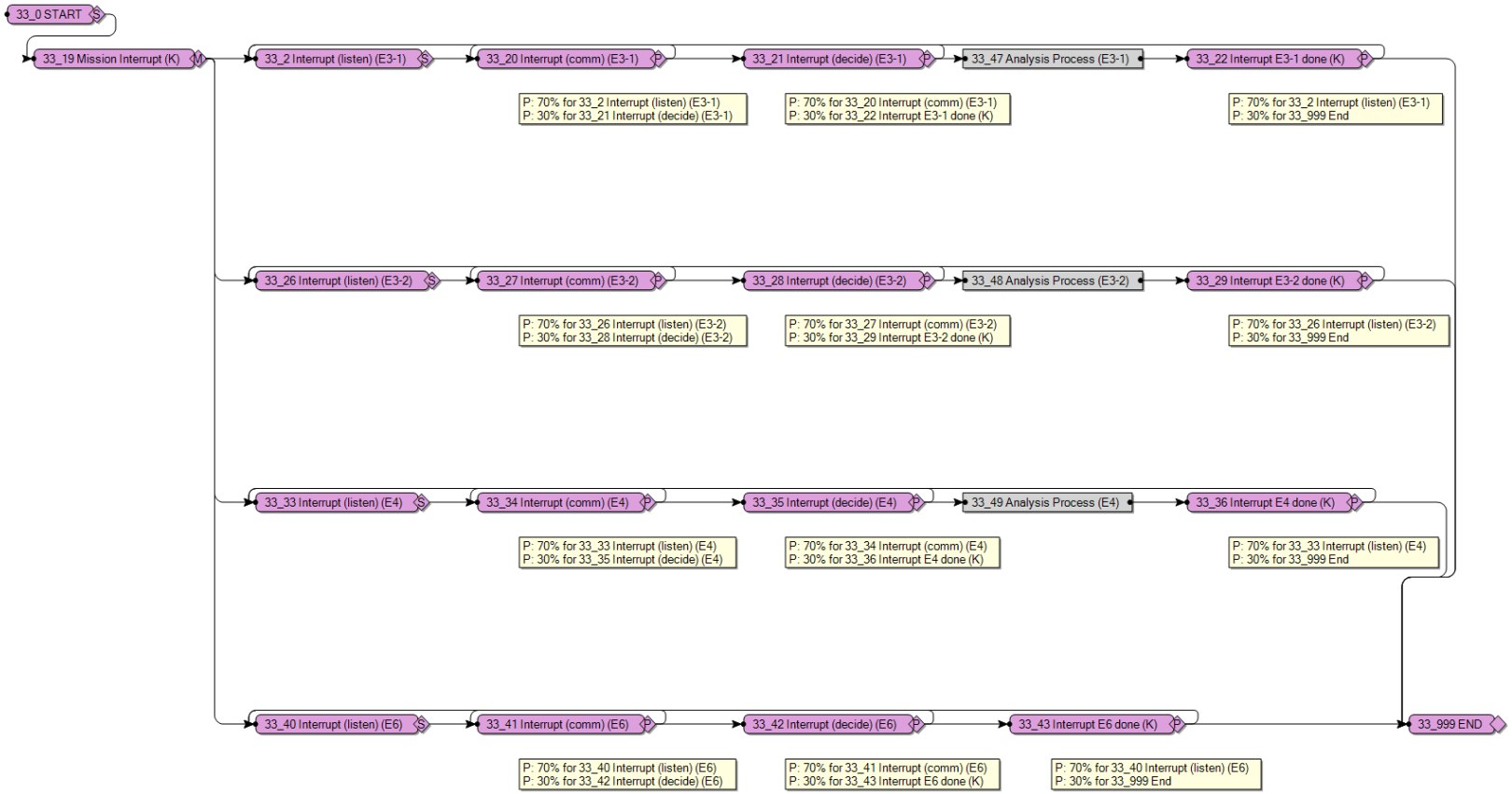

Figure A-5. Baseline Function *Mission Interrupt* (from page 8).

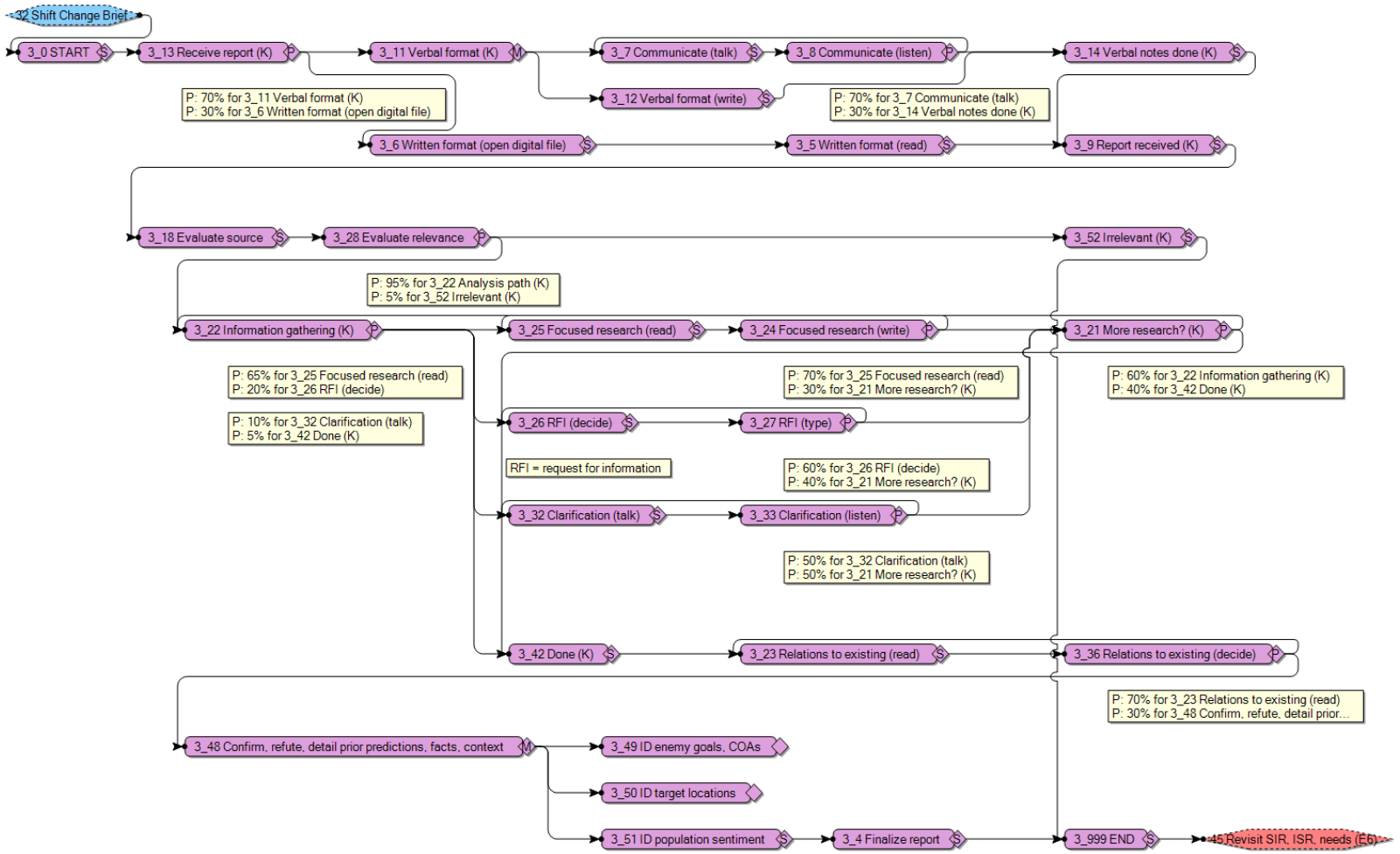

Figure A-6. Baseline Function Analysis Process (from page 9).

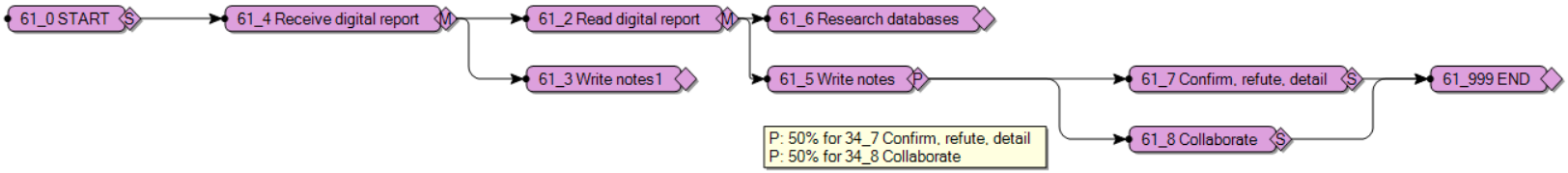

Figure A-7. Baseline Function *Small Report* (from page 10).

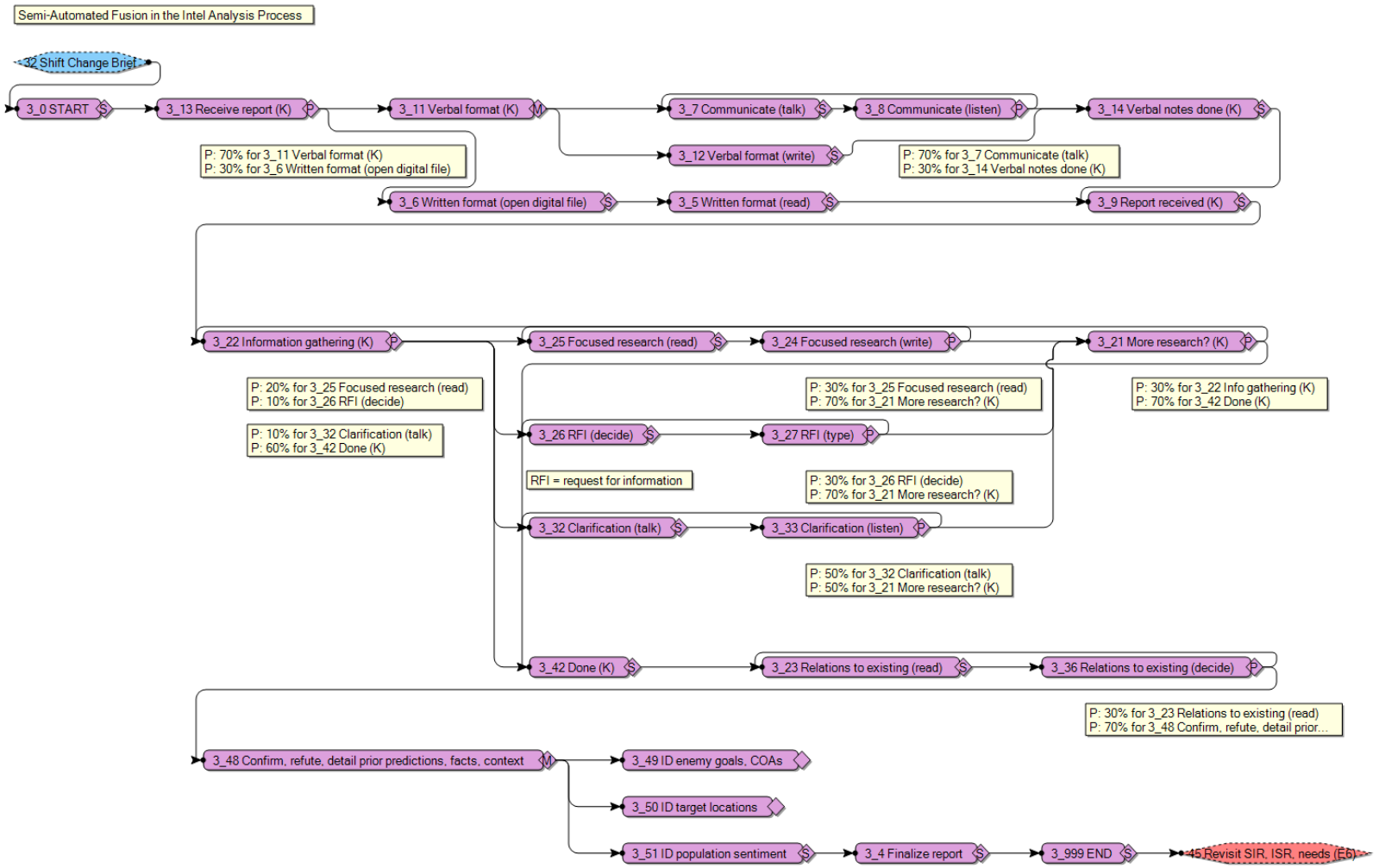

Figure A-8. SAF Function *Analysis Process* (from page 11).

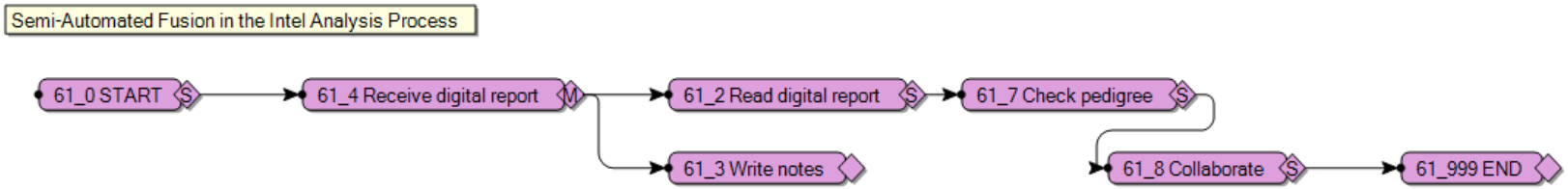

Figure A-9. SAF Function *Small Report* (from page 12).

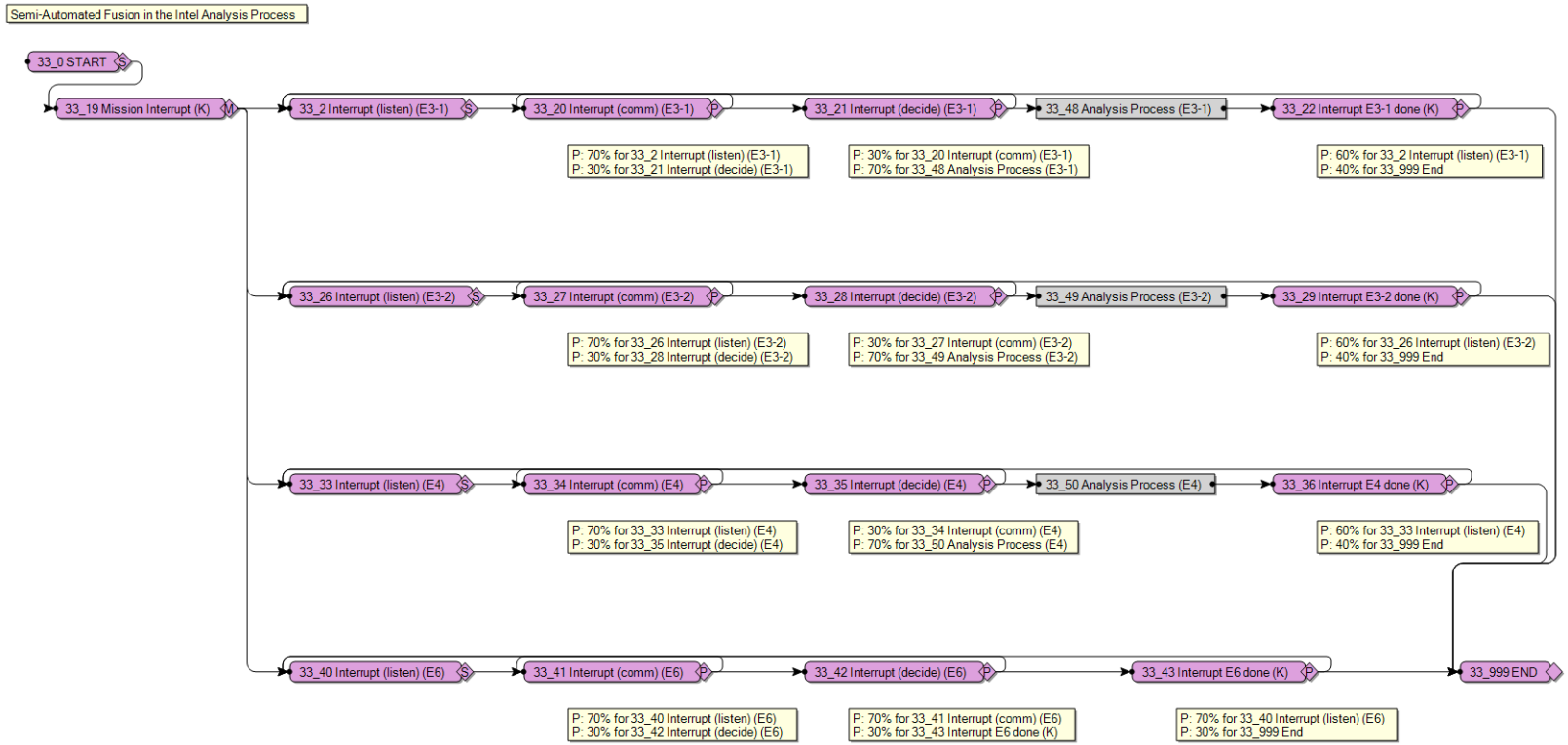

Figure A-10. SAF Function *Mission Interrupt* (from page 13).

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Appendix B. Workload Graphs

Figures B-1 through B-4 shows the workload graphs.

This appendix appears in its original form, without editorial change.

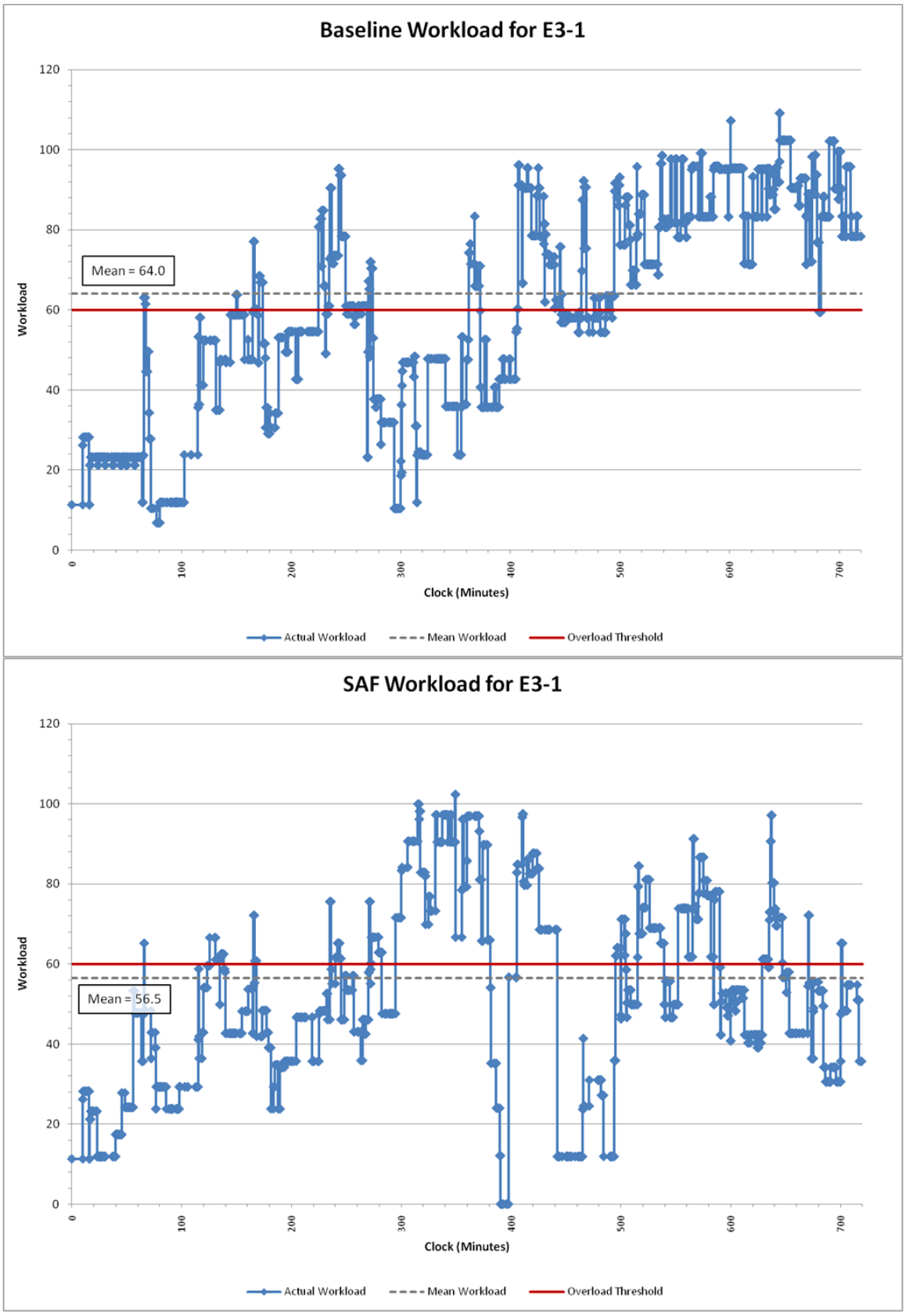
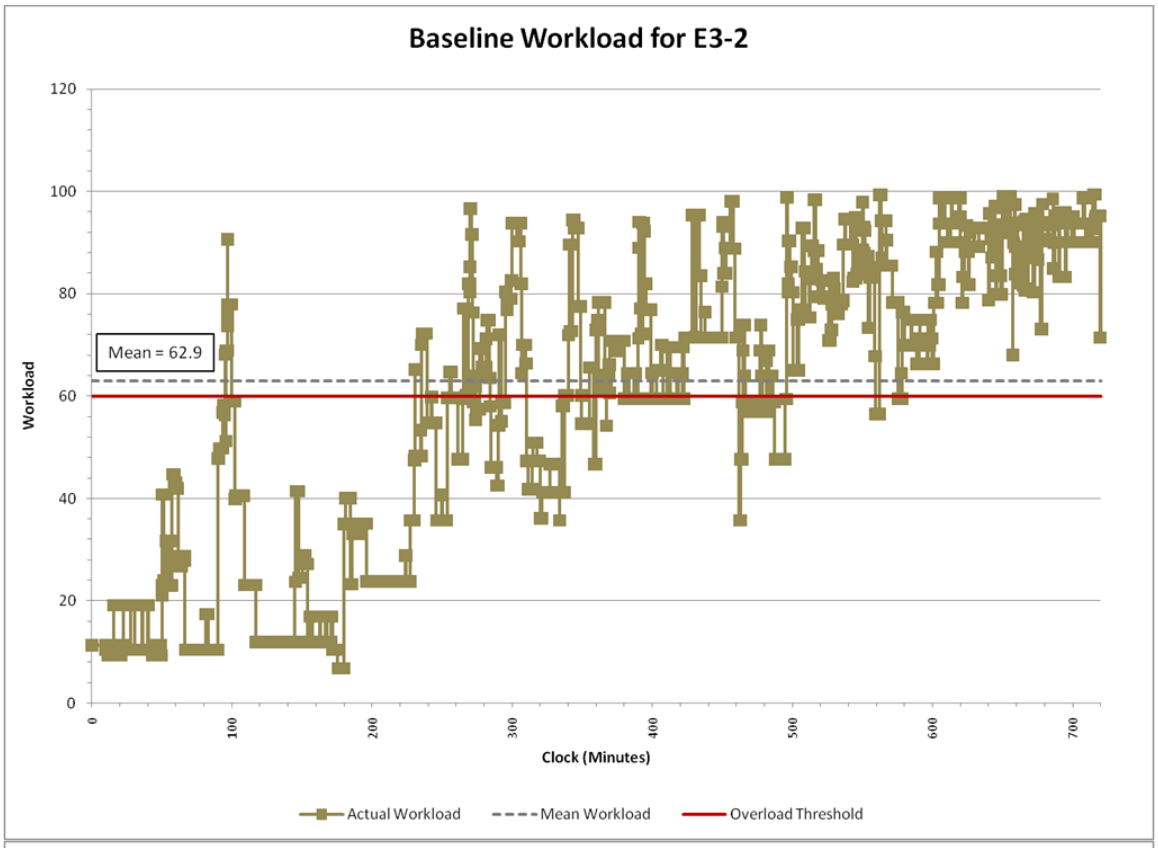


Figure B-1. Baseline and SAF workload for E3-1.



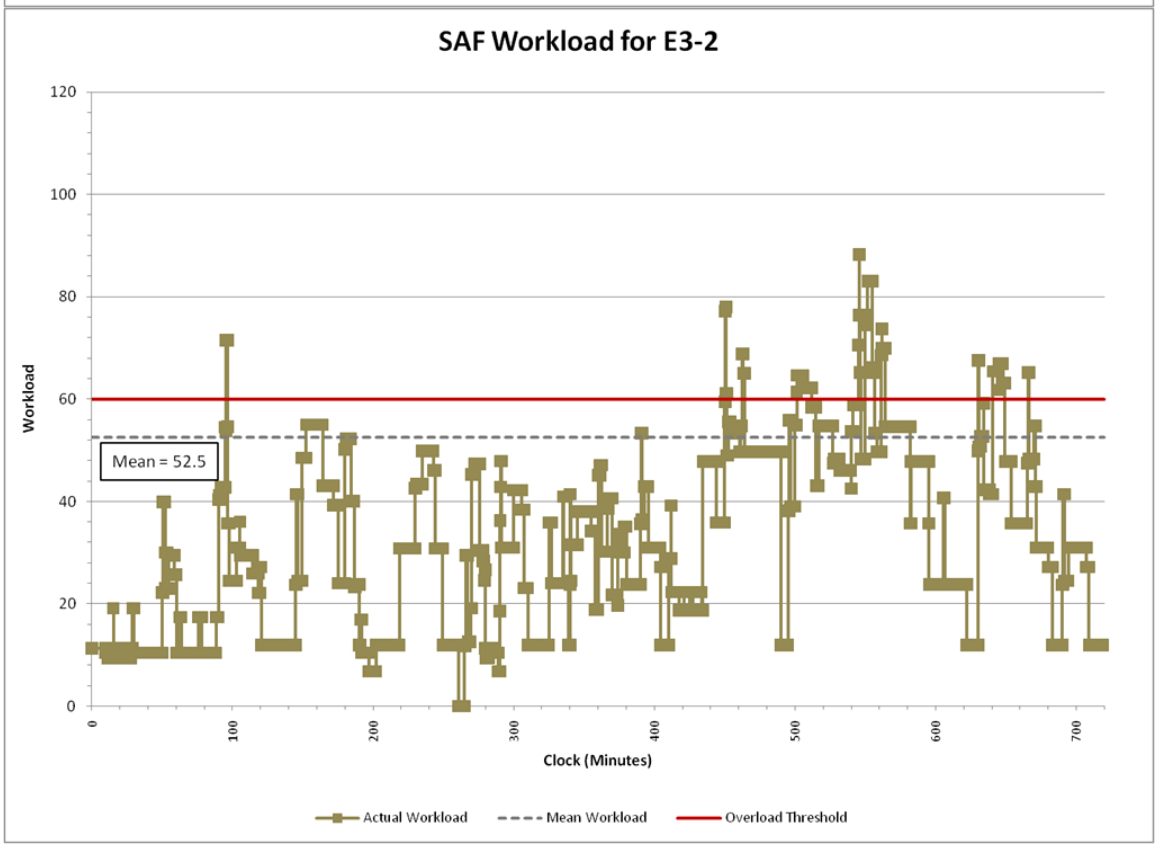


Figure B-2. Baseline and SAF workload for E3-2

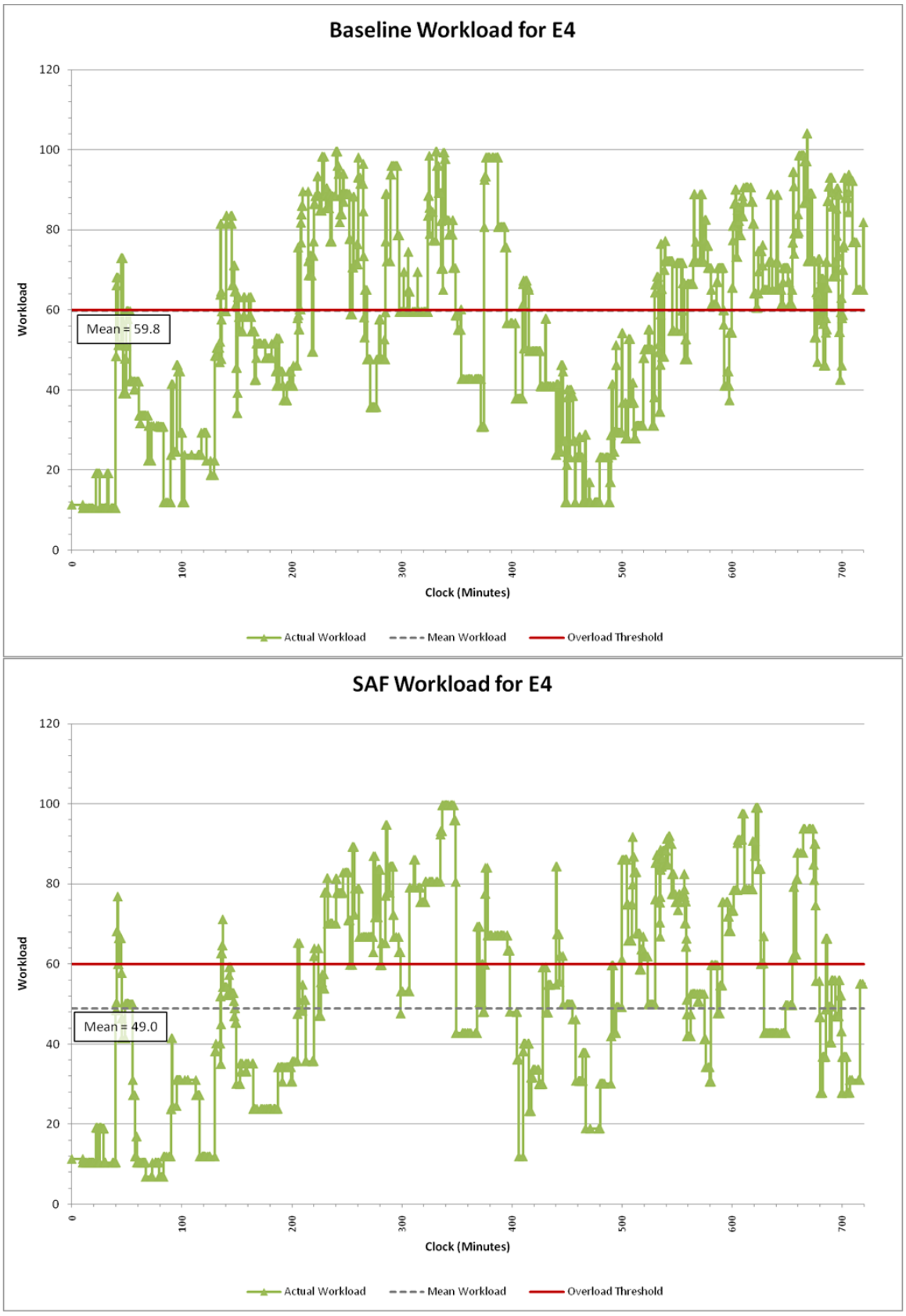
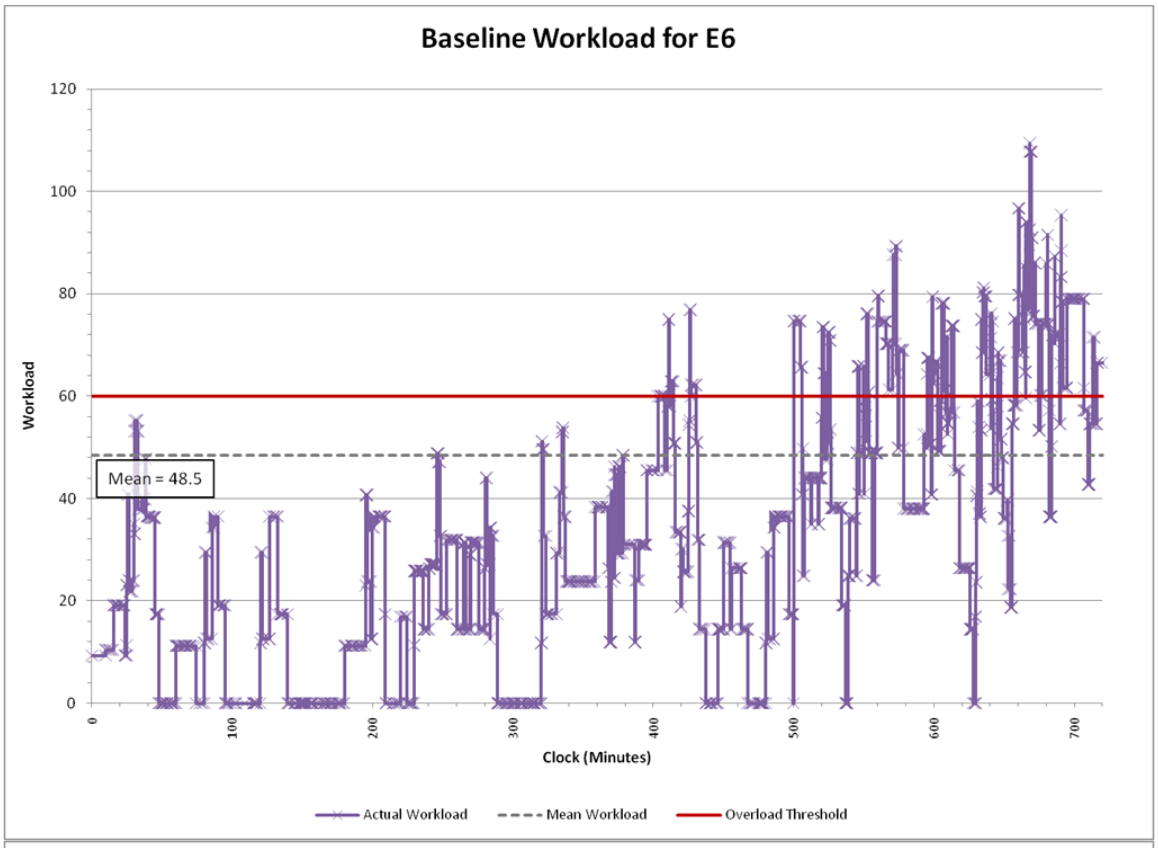


Figure B-3. Baseline and SAF workload for E4.



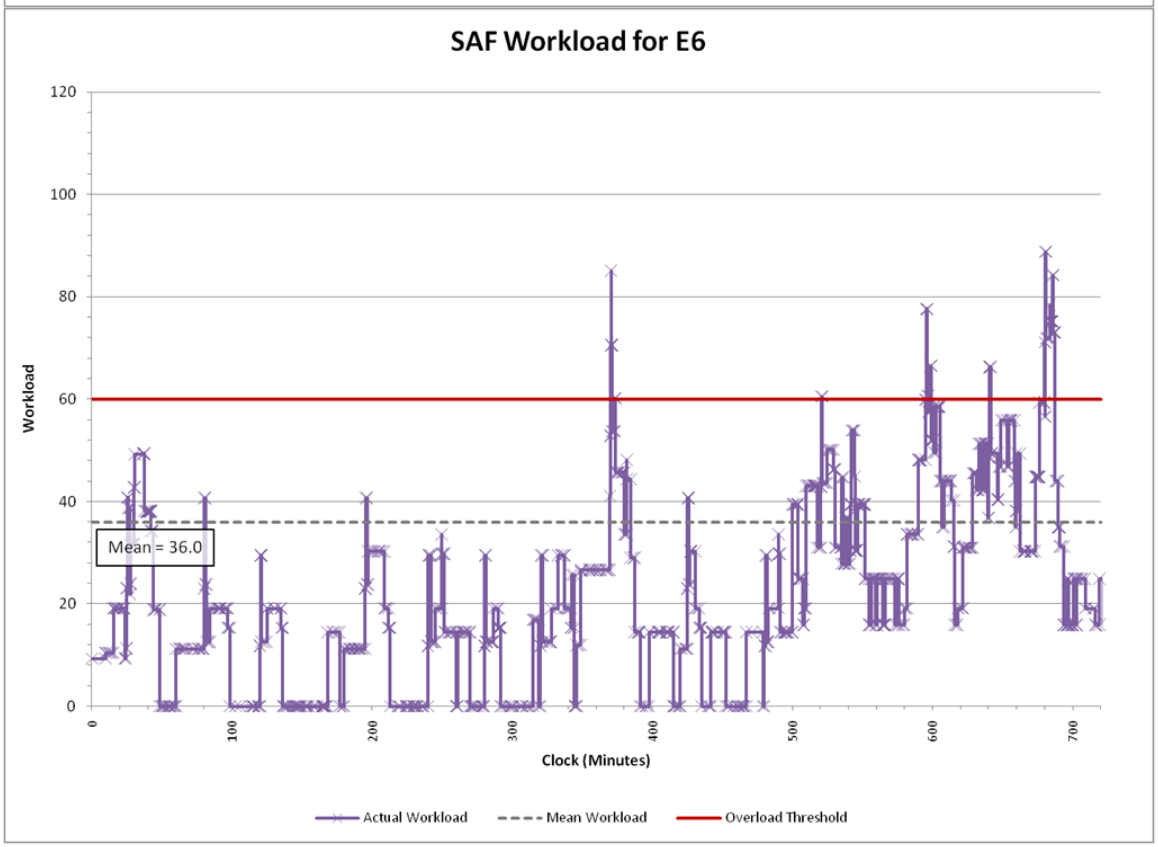


Figure B-4. Baseline and SAF workload for E6.

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List of Symbols, Abbreviations, and Acronyms

COA	course of action
IMPRINT	Improved Performance Research Integration Tool
ISR	Intelligence, Surveillance, and Reconnaissance
MOS	military occupational specialty
PIR	priority intelligence requirement
RFI	Request for Information
SAF	semi-automated fusion
SIR	Specific Information Requirements

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